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SECTION

3 OF 6

Table 3-1. RESRAD Key Input Parameters and Values for Residential Farmer. (6 sheets)

RESRAD v 6.3; Pathways = plant and soil ingestion, inhalation of particulates, external radiation, and inhalation of radon			
	UNITS	**VALUE**	**COMMENTS**
Solubility limit	mol/L	0	*default value*
Leach rate	/yr	0	*default value*
Use plant/soil ratio?	yes/no	no	*default value*
CALCULATION TIMES			
1	years	0	site-specific
2	years	17	site-specific
3	years	28	site-specific
4	years	150	site-specific
5	years	500	site-specific
6	years	1,000	site-specific
CONTAMINATED ZONE PARAMETERS			
Area of contaminated zone	square meters	100	Site-specific; size of a garden (p. 25, Rittman, 2004)
Thickness of contaminated zone	meters	0.15	Site-specific; tilling depth (p. 25, Rittman, 2004)
Length parallel to aquifer flow	meters	9.1	site-specific information used for all sites (30 ft; or 9.1m)
COVER/HYDROL			**Contaminated Zone = Hanford Sands**
Cover depth	meters	0	*default value*
Density of cover material	grams/cm^3	greyed out	*default value = 1.5*
Cover erosion rate	meters/yr	greyed out	*default value = 0.001*
Density of contaminated zone	grams/cm^3	1.85	Hanford Sands = 1.4–2.3
Contaminated zone erosion rate	meters/yr	0	Set to zero
Contaminated zone total porosity		0.3	Hanford Sands value
Contaminated zone field capacity		0.1	Hanford Sands value
Contaminated zone hydraulic conductivity	meters/yr	1,577	Hanford Sands = 0.005 cm/s; 1,577 m/yr
Contaminated zone b parameter		4.05	RESRAD value for sand from Appendix E
Humidity in air	grams/cm^3	greyed out	*default value*
Evapotranspiration coefficient		0.5	*default value*
Wind speed	meters/s	3.4	site-specific
Precipitation	meters/yr	1	*default value*
Irrigation	meters/yr	0	assume for Hanford Sands (default was 0.2)

Table 3-1. RESRAD Key Input Parameters and Values for Residential Farmer. (6 sheets)

RESRAD v 6.3; Pathways = plant and soil ingestion, inhalation of particulates, external radiation, and inhalation of radon			
	UNITS	**VALUE**	**COMMENTS**
Irrigation mode (overhead or ditch?)		overhead	*default value*
Runoff coefficient		0	assume for Hanford Sands (default was 0.2)
Watershed area for nearby stream or pond	square meters	1,000,000	*default value*
Accuracy for water/soil computations		0.001	*default value*
SATURATED ZONE			**Saturated Zone = Ringold**
Density of saturated zone	grams/cm^3	1.5	*default value*
Saturated zone total porosity		0.33	Ringold value
Saturated zone effective porosity		0.18	Ringold value
Saturated zone field capacity		0.21	Ringold value
Saturated zone hydraulic conductivity	meters/yr	7,300	Ringold value = 7,300 m/yr
Saturated zone hydraulic gradient		0.002	Ringold value
Saturated zone b parameter		4.05	RESRAD value for sand from Appendix E
Water table drop rate	meters/yr	0.2	Ringold value
Well pump intake depth	m below water table	10	*default value*
Model for water transport parameters (nondispersion or mass-balance)		nondispersion	*default value*
Well pumping rate	cubic meters/yr	30,000	10-20 gal/min or approx. 20,000–40,000 cubic meters/yr
UNSATURATED			**Unsaturated Zones = Hanford Sands, CCU, and Ringold**
Number of unsaturated zones	**3**		number of zones set manually
Unsaturated Zone #1	Hanford Sands		
Thickness	meters	33.5	110 ft; 33.5 m
Density	grams/cm^3	1.85	Hanford Sands = 1.4–2.3; WHC-EP-0883, Appendix A
Total porosity		0.3	Hanford Sands value; WHC-EP-0883, Appendix A
Effective porosity		0.25	Hanford Sands value; WHC-EP-0883, Appendix A
Field capacity		0.25	Hanford Sands value; WHC-EP-0883, Appendix A
Hydraulic conductivity	meters/yr	1,577	Hanford Sands = 0.005 cm/s; 1,577 m/yr; WHC-EP-0883, Appendix A
b parameter		4.05	RESRAD value for sand from Appendix E; Table E.2

Table 3-1. RESRAD Key Input Parameters and Values for Residential Farmer. (6 sheets)

RESRAD v 6.3; Pathways = plant and soil ingestion, inhalation of particulates, external radiation, and inhalation of radon			
	UNITS	**VALUE**	**COMMENTS**
Unsaturated Zone #2	CCU (silt values; ignored caliche for model)		
Thickness	meters	3.1	10 ft; 3.1 m
Density	grams/cm^3	2.0	CCU (silt) value; WHC-EP-0883, Appendix A
Total porosity		0.37	CCU (silt) value; WHC-EP-0883, Appendix A
Effective porosity		0.29	CCU (silt) value; WHC-EP-0883, Appendix A
Field capacity		0.29	CCU (silt) value; WHC-EP-0883, Appendix A
Hydraulic conductivity	meters/yr	2,740	CCU value = 8.69E-03 cm/sec; 2,740 m/yr; WHC-EP-0883, Appendix A
b parameter		5.3	RESRAD value for silty loam from Appendix E; Table E.2
Unsaturated Zone #3	Ringold		
Thickness	meters	32.3	106 ft; 32.3 m
Density	grams/cm^3	1.85	Ringold = 1.4–2.3; WHC-EP-0883, Appendix A
Total porosity		0.22	Ringold value; WHC-EP-0883, Appendix A
Effective porosity		0.13	Ringold value; WHC-EP-0883, Appendix A
Field capacity		0.13	Ringold value; WHC-EP-0883, Appendix A
Hydraulic conductivity	meters/yr	7,300	Ringold = 7,300 m/yr; WHC-EP-0883, Appendix A
b parameter		4.05	RESRAD value for sand from Appendix E; Table E.2
OCCUPANCY			
Inhalation rate	m^3/year	8,400	*default value*
Mass loading for inhalation	g/m^3	3.70E-07	Site-specific based on a PEF of 2.72E+09
Exposure duration	years	30	*default value*
Indoor dust filtration factor		0.4	*default value*
External gamma shielding factor		0.7	*default value*
Indoor time fraction		0.5	*default value*
Outdoor time fraction		0.25	*default value*
Shape of contaminated zone		circular	*default*

Table 3-1. RESRAD Key Input Parameters and Values for Residential Farmer. (6 sheets)

RESRAD v 6.3; Pathways = plant and soil ingestion, inhalation of particulates, external radiation, and inhalation of radon			
	UNITS	**VALUE**	**COMMENTS**
INGESTION–Dietary			
Fruits, vegetables and grain	kg/year	106	*Site-specific value; includes ingestion of fruits and vegetables only*
Leafy vegetable	kg/year	10.5	*Site-specific value; assuming 9% of fruit/vegetables intake is leafy*
Milk	L/year	greyed out	*This pathway was not used (default = 92)*
Meat and poultry	kg/year	greyed out	*This pathway was not used (default = 23)*
Soil Ingestion	g/year	36.5	*default value*
Contamination fraction–drinking water		greyed out	*This pathway was not used (default = 1)*
Contamination fraction–household water		1	*This pathway was not used*
Contamination fraction–livestock water		greyed out	*This pathway was not used (default = 1)*
Contamination fraction–irrigation water		1	*This pathway was not used*
Contamination fraction–plant food		1	Assumes 100% contaminated fraction
Contamination fraction–meat		0	*This pathway was not used*
Contamination fraction–milk		0	*This pathway was not used*
INGESTION–Non-Dietary			
Livestock fodder intake from meat	kg/day	greyed out	*This pathway was not used (default = 68)*
Fodder intake from milk	kg/day	greyed out	*This pathway was not used (default = 55)*
Livestock water intake for meat	L/day	greyed out	*This pathway was not used (default = 50)*
Livestock water intake for milk	L/day	greyed out	*This pathway was not used (default = 160)*
Livestock water intake of soil		greyed out	*This pathway was not used (default = 0.5)*
Drinking water fraction from groundwater		greyed out	*This pathway was not used (default = 1)*
Household water fraction from groundwater		1	*This pathway was not used*
Livestock water fraction from groundwater		greyed out	*This pathway was not used (default = 1)*
Irrigation fraction from groundwater		1	*This pathway was not used*
Mass loading for foliar deposition	g/m^3	0.0001	*This pathway was not used*
Depth of soil mixing layer	M	0.15	*This pathway was not used*
Depth of roots	M	0.9	*This pathway was not used*
PLANT FACTORS			
Wet weight crop yield for non-leafy	kg/m^2	0.7	*default value*
Wet weight crop yield for leafy	kg/m^2	1.5	*default value*

Table 3-1. RESRAD Key Input Parameters and Values for Residential Farmer. (6 sheets)

RESRAD v 6.3; Pathways = plant and soil ingestion, inhalation of particulates, external radiation, and inhalation of radon			
	UNITS	VALUE	COMMENTS
Wet weight crop yield for fodder	kg/m^2	greyed out	*This pathway was not used (default = 1.1)*
Growing season for non-leafy	years	0.17	*default value*
Growing season for leafy	years	0.25	*default value*
Growing season for fodder	years	greyed out	*This pathway was not used (default = 0.08)*
Translocation factor for non-leafy		0.1	*default value*
Translocation factor for leafy		1	*default value*
Translocation factor for fodder		greyed out	*This pathway was not used (default = 1)*
Dry foliar interception fraction for non-leafy		0.25	*default value*
Dry foliar interception fraction for leafy		0.25	*default value*
Dry foliar interception fraction for fodder		greyed out	*This pathway was not used (default = 0.25)*
Wet foliar interception fraction for non-leafy		0.25	*default value*
Wet foliar interception fraction for leafy		0.25	*default value*
Wet foliar interception fraction for fodder		greyed out	*This pathway was not used (default = 0.25)*
Weathering removal constant for vegetation		20	*default value*
Radon Data			
Cover total porosity		0.4	*default value*
Cover volumetric water content		0.05	*default value*
Cover radon diffusion coefficient	m^2sec	0.000002	*default value*
Bldg foundation thickness	meters	0.15	*default value*
Bldg foundation density	g/cm^3	2.4	*default value*
Bldg foundation total Porosity		0.1	*default value*
Bldg foundation volumetric water content		0.03	*default value*
Bldg foundation radon diffusion coefficient	m^2/sec	0.0000003	*default value*
Contaminated radon diffusion coefficient	m^2/sec	0.000002	*default value*
Radon vertical dimension of mixing	meters	2	*default value*
Building air exchange rate	1/hr	0.5	*default value*
Height of bldg. (room)	meters	2.5	*default value*
Building indoor area factor		0	*default value*
Foundation depth below ground surface	meters	-1	*default value*
Ra-222 emanation coefficient		0.25	*default value*

Table 3-1. RESRAD Key Input Parameters and Values for Residential Farmer. (6 sheets)

RESRAD v 6.3; Pathways = plant and soil ingestion, inhalation of particulates, external radiation, and inhalation of radon			
	UNITS	**VALUE**	**COMMENTS**
Ra-220 emanation coefficient		0.15	*default value*
Storage Times			
Fruits, non-leafy vegetables, and grain	days	14	*default value*
Leafy vegetables	days	1	*default value*
Milk	days	greyed out	*This pathway was not used (default = 1)*
Meat and poultry	days	greyed out	*This pathway was not used (default = 20)*
Fish	days	greyed out	*This pathway was not used (default = 7)*
Crustacea and mollusks	days	greyed out	*This pathway was not used (default = 7)*
Well water	days	1	*default value*
Surface water	days	1	*default value*
Livestock fodder	days	greyed out	*This pathway was not used (default = 45)*
C-14			**For Site A-8 only**
Concentration in local water	g/cm^3	0.00002	*default value*
Concentration in contaminated soil	g/g	0.03	*default value*
Fraction of vegetation in carbon absorbed from soil		0.02	*default value*
Fraction of vegetation in carbon absorbed from air		0.98	*default value*
Thickness of evasion layer of C-14 in soil	meters	0.3	*default value*
C-14 evasion flux rate from soil	1/sec	0.0000007	*default value*
C-12 evasion flux rate from soil	1/sec	1.00E-10	*default value*
Grain fraction in livestock feed (balance is hay/fodder)			*default value*
Beef cattle		0.8	*default value*
Milk cow		0.2	*default value*
DCF correction factor for gaseous forms of C-14		88.94	*default value*

Table 3-2. RESRAD Key Input Parameters and Values for Construction Worker. (5 sheets)

RESRAD v 6.3; Pathways = soil ingestion, inhalation of particulates, inhalation of radon			
	UNITS	**VALUE**	**COMMENTS**
SOIL CONCENTRATIONS			
Basic radiation dose limit	mrem/yr	25	*default value*
Number of nuclides		varies	Depends on the site
Nuclide (#1)		varies	Depends on the site
Nuclide (#1) concentration	pCi/g		site-specific concentration set manually
Transport factors (for nuclide #1):	-----	-----	-----
Contaminated zone distribution coefficient	cm^3/g	varies	*chemical-specific*
Saturated zone distribution coefficient	cm^3/g	varies	*chemical-specific*
Number of Unsaturated Zones = 3	-----	-----	-----
Unsaturated Zone 1 distribution coefficient	cm^3/g	varies	*chemical-specific*
Unsaturated Zone 2 distribution coefficient	cm^3/g	varies	*chemical-specific*
Unsaturated Zone 3 distribution coefficient	cm^3/g	varies	*chemical-specific*
Options:	-----	-----	-----
Water concentration: time since material placement	year	0	*default value*
Water concentration: groundwater concentration	pCi/L	greyed out (t=0)	*default value*
Solubility limit	mol/L	0	*default value*
Leach rate	/yr	0	*default value*
Use plant/soil ratio?	yes/no	no	*default value*
Nuclide (#2)		varies	Depends on the site
Nuclide (#2) concentration	pCi/g		site-specific concentration set manually
Transport factors (for nuclide #2):	-----	-----	-----
Contaminated zone distribution coefficient	cm^3/g	varies	*chemical-specific*
Saturated zone distribution coefficient	cm^3/g	varies	*chemical-specific*
Number of Unsaturated Zones = 3	-----	-----	-----
Unsaturated Zone 1 distribution coefficient	cm^3/g	varies	*chemical-specific*
Unsaturated Zone 2 distribution coefficient	cm^3/g	varies	*chemical-specific*
Unsaturated Zone 3 distribution coefficient	cm^3/g	varies	*chemical-specific*
Options:	-----	-----	-----
Water concentration: time since material placement	year	0	*default value*

Table 3-2. RESRAD Key Input Parameters and Values for Construction Worker. (5 sheets)

RESRAD v 6.3; Pathways = soil ingestion, inhalation of particulates, inhalation of radon			
	UNITS	**VALUE**	**COMMENTS**
Water concentration: groundwater concentration	pCi/L	greyed out (t=0)	*default value*
Solubility limit	mol/L	0	*default value*
Leach rate	/yr	0	*default value*
Use plant/soil ratio?	yes/no	no	*default value*
CALCULATION TIMES			
1	years	0	site-specific
2	years	17	site-specific
3	years	28	site-specific
4	years	150	site-specific
5	years	500	site-specific
6	years	1,000	site-specific
CONTAMINATED ZONE PARAMETERS			
Area of contaminated zone	square meters	1,811.61 / 2.323 / 1579.35	Site-specific for Z-1A / Z-8 / A-8
Thickness of contaminated zone	meters	28.04 / 5.79 / 18.14	Site-specific for Z-1A / Z-8 / A-8
Length parallel to aquifer flow	meters	9.1	site-specific information used for all sites (30 ft; or 9.1m)
COVER/HYDROL			**Contaminated Zone = Hanford Sands**
Cover depth	meters	0	*default value*
Density of cover material	grams/cm^3	greyed out	*default value = 1.5*
Cover erosion rate	meters/yr	greyed out	*default value =*
Density of contaminated zone	grams/cm^3	1.85	Hanford Sands = 1.4–2.3
Contaminated zone erosion rate	meters/yr	0.001	*default value*
Contaminated zone total porosity		0.3	Hanford Sands value
Contaminated zone field capacity		0.1	Hanford Sands value
Contaminated zone hydraulic conductivity	meters/yr	1,577	Hanford Sands = 0.005 cm/s; 1,577 m/yr
Contaminated zone b parameter		4.05	RESRAD value for sand from Appendix E
Humidity in air	grams/cm^3	greyed out	*default value*
Evapotranspiration coefficient		0.5	*default value*
Wind speed	meters/s	3.4	site-specific

Table 3-2. RESRAD Key Input Parameters and Values for Construction Worker. (5 sheets)

RESRAD v 6.3; Pathways = soil ingestion, inhalation of particulates, inhalation of radon			
	UNITS	**VALUE**	**COMMENTS**
Precipitation	meters/yr	1	*default value*
Irrigation	meters/yr	0	assume for Hanford Sands (default was 0.2)
Irrigation mode (overhead or ditch?)		overhead	*default value*
Runoff coefficient		0	assume for Hanford Sands (default was 0.2)
Watershed area for nearby stream or pond	square meters	1,000,000	*default value*
Accuracy for water/soil computations		0.001	*default value*
SATURATED ZONE			**Saturated Zone = Ringold**
Density of saturated zone	grams/cm^3	1.5	*default value*
Saturated zone total porosity		0.33	Ringold value
Saturated zone effective porosity		0.18	Ringold value
Saturated zone field capacity		0.21	Ringold value
Saturated zone hydraulic conductivity	meters/yr	7,300	Ringold value = 7,300 m/yr
Saturated zone hydraulic gradient		0.002	Ringold value
Saturated zone b parameter		4.05	RESRAD value for sand from Appendix E
Water table drop rate	meters/yr	0.2	Ringold value
Well pump intake depth	m below water table	10	*default value*
Model for water transport parameters (nondispersion or mass-Balance)		nondispersion	*default value*
Well pumping rate	cubic meters/yr	30,000	10-20 gal/min or approx. 20,000–40,000 cubic meters/yr
UNSATURATED			**Unsaturated Zones = Hanford Sands, CCU, and Ringold**
Number of unsaturated zones	**3**		number of zones set manually
Unsaturated Zone #1	Hanford Sands		
Thickness	meters	33.5	110 ft; 33.5 m
Density	grams/cm^3	1.85	Hanford Sands = 1.4–2.3; WHC-EP-0883, Appendix A
Total porosity		0.3	Hanford Sands value; WHC-EP-0883, Appendix A
Effective porosity		0.25	Hanford Sands value; WHC-EP-0883, Appendix A
Field capacity		0.25	Hanford Sands value; WHC-EP-0883, Appendix A
Hydraulic conductivity	meters/yr	1,577	Hanford Sands = 0.005 cm/s; 1,577 m/yr; WHC-EP-0883, Appendix A
b parameter		4.05	RESRAD value for sand from Appendix E; Table E.2

Table 3-2. RESRAD Key Input Parameters and Values for Construction Worker. (5 sheets)

RESRAD v 6.3; Pathways = soil ingestion, inhalation of particulates, inhalation of radon			
	UNITS	**VALUE**	**COMMENTS**
Unsaturated Zone #2	CCU (silt values; ignored caliche for model)		
Thickness	meters	3.1	10 ft; 3.1 m
Density	grams/cm^3	2.0	CCU (silt) value; WHC-EP-0883, Appendix A
Total porosity		0.37	CCU (silt) value; WHC-EP-0883, Appendix A
Effective porosity		0.29	CCU (silt) value; WHC-EP-0883, Appendix A
Field capacity		0.29	CCU (silt) value; WHC-EP-0883, Appendix A
Hydraulic conductivity	meters/yr	2,740	CCU value = 8.69E-03 cm/sec; 2,740 m/yr; WHC-EP-0883, Appendix A
b parameter		5.3	RESRAD value for silty loam from Appendix E; Table E.2
Unsaturated Zone #3	Ringold		
Thickness	meters	32.3	106 ft; 32.3 m
Density	grams/cm^3	1.85	Ringold = 1.4–2.3; WHC-EP-0883, Appendix A
Total porosity		0.22	Ringold value; WHC-EP-0883, Appendix A
Effective porosity		0.13	Ringold value; WHC-EP-0883, Appendix A
Field capacity		0.13	Ringold value; WHC-EP-0883, Appendix A
Hydraulic conductivity	meters/yr	7,300	Ringold = 7,300 m/yr; WHC-EP-0883, Appendix A
b parameter		4.05	RESRAD value for sand from Appendix E; Table E.2
OCCUPANCY			
Inhalation rate	m^3/yr	600	Assumes 20 m^3/day for 30 days/yr
Mass loading for inhalation	g/m^3	0.0001	*default value*
Exposure duration	years	1	Standard exposure duration for construction workers (EPA, 2002)
Indoor dust filtration factor		0	Receptors will spend all of their time outdoors
External gamma shielding factor		greyed out	Not pertinent to soil ingestion, inhalation of particulates, or inhalation of radon routes of exposure
Indoor time fraction		0	Receptors will spend all of their time outdoors
Outdoor time fraction		1	Receptors will spend all of their time outdoors
Shape of contaminated zone		circular	*default*

Table 3-2. RESRAD Key Input Parameters and Values for Construction Worker. (5 sheets)

RESRAD v 6.3; Pathways = soil ingestion, inhalation of particulates, inhalation of radon			
	UNITS	**VALUE**	**COMMENTS**
INGESTION–Dietary			
Soil ingestion	g/yr	9.9	Assumes 0.33 g/day for construction workers (EPA, 2002) for 30 days/yr
Household water		0	Set to zero because receptor is not exposed to household water
INGESTION–NON DIETARY			
Depth of soil mixing layer	m	0.15	*default value*
Groundwater fractional usage (balance from surface water)–drinking water		0	Set to zero because receptor is not exposed to household water
Radon Data			
Cover total porosity		0	Set to zero because cover depth is zero
Cover volumetric water content		0	Set to zero because cover depth is zero
Cover radon diffusion coefficient	m^2/sec	0	Set to zero because cover depth is zero
Bldg foundation thickness	meters	0	Set to zero because time indoors is zero
Bldg foundation density	g/cm^3	0	Set to zero because time indoors is zero
Bldg foundation total porosity		0.0001	Set to zero because time indoors is zero
Bldg foundation volumetric water content		0	Set to zero because time indoors is zero
Bldg foundation radon diffusion coefficient	m^2/sec	0	Set to zero because time indoors is zero
Contaminated radon diffusion coefficient	m^2/sec	0.000002	*default value*
Radon vertical dimension of mixing	meters	2	*default value*
Building air exchange rate	1/hr	0	Set to zero because time indoors is zero
Building room height	meters	0.001	Set to small number because time indoors is zero
Building indoor area factor		0	Set to zero because time indoors is zero
Foundation depth below ground surface	meters	-1	*default value*
Ra-222 emanation coefficient		0.25	*default value*
Ra-222 emanation coefficient		0.15	*default value*
Storage Times	**greyed out**		

Table 3-3. RESRAD Key Input Parameters and Values for Well Driller. (5 sheets)

RESRAD v 6.3; Pathways = soil ingestion, inhalation of particulates, inhalation of radon			
	UNITS	**VALUE**	**COMMENTS**
SOIL CONCENTRATIONS			
Basic radiation dose limit	mrem/yr	25	*default value*
Number of nuclides		varies	Depends on the site
Nuclide (#1)		varies	Depends on the site
Nuclide (#1) concentration	pCi/g		site-specific concentration set manually
Transport factors (for nuclide #1):	-----	-----	-----
Contaminated zone distribution coefficient	cm^3/g	varies	*chemical-specific*
Saturated zone distribution coefficient	cm^3/g	varies	*chemical-specific*
Number of Unsaturated Zones = 3	-----	-----	-----
Unsaturated zone 1 distribution coefficient	cm^3/g	varies	*chemical-specific*
Unsaturated zone 2 distribution coefficient	cm^3/g	varies	*chemical-specific*
Unsaturated zone 3 distribution coefficient	cm^3/g	varies	*chemical-specific*
Options:	-----	-----	-----
Water Concentration: Time since material placement	year	0	*default value*
Water concentration: groundwater concentration	pCi/L	greyed out (t=0)	*default value*
Solubility limit	mol/L	0	*default value*
Leach rate	/yr	0	*default value*
Use Plant/Soil ratio?	yes/no	no	*default value*
Nuclide (#2)		varies	Depends on the site
Nuclide (#2) concentration	pCi/g		site-specific concentration set manually
Transport Factors (for nuclide #2):	-----	-----	-----
Contaminated zone distribution coefficient	cm^3/g	varies	*chemical-specific*
Saturated zone distribution coefficient	cm^3/g	varies	*chemical-specific*
Number of Unsaturated Zones = 3	-----	-----	-----
Unsaturated zone 1 distribution coefficient	cm^3/g	varies	*chemical-specific*
Unsaturated zone 2 distribution coefficient	cm^3/g	varies	*chemical-specific*
Unsaturated zone 3 distribution coefficient	cm^3/g	varies	*chemical-specific*
Options:	-----	-----	-----
Water Concentration: Time since material placement	year	0	*default value*
Water concentration: groundwater concentration	pCi/L	greyed out (t=0)	*default value*
Solubility limit	mol/L	0	*default value*

Table 3-3. RESRAD Key Input Parameters and Values for Well Driller. (5 sheets)

RESRAD v 6.3; Pathways = soil ingestion, inhalation of particulates, inhalation of radon			
	UNITS	**VALUE**	**COMMENTS**
Leach rate	/yr	0	*default value*
Use plant/soil ratio?	yes/no	no	*default value*
CALCULATION TIMES			
1	years	0	site-specific
2	years	17	site-specific
3	years	28	site-specific
4	years	150	site-specific
5	years	500	site-specific
6	years	1,000	site-specific
CONTAMINATED ZONE PARAMETERS			
Area of contaminated zone	square meters	80	Site-specific; well tailings spread over area (p. 21, Rittman, 2004)
Thickness of contaminated zone	meters	0.05	Site-specific; layer of contaminated soil surrounding driller (p. 21, Rittman, 2004)
Length parallel to aquifer flow	meters	9.1	site-specific information used for all sites (30 ft; or 9.1m)
COVER/HYDROL			**Contaminated Zone = Hanford Sands**
Cover depth	meters	0	*default value*
Density of cover material	grams/cm^3	greyed out	*default value = 1.5*
Cover erosion rate	meters/yr	greyed out	*default value =*
Density of contaminated zone	grams/cm^3	1.85	Hanford Sands = 1.4–2.3
Contaminated zone erosion rate	meters/yr	0	Set to zero
Contaminated zone total porosity		0.3	Hanford Sands value
Contaminated zone field capacity		0.1	Hanford Sands value
Contaminated zone hydraulic conductivity	meters/yr	1,577	Hanford Sands = 0.005 cm/s; 1,577 m/yr
Contaminated zone b parameter		4.05	RESRAD value for sand from Appendix E
Humidity in air	grams/cm^3	greyed out	*default value*
Evapotranspiration coefficient		0.5	*default value*
Wind speed	meters/s	3.4	site-specific
Precipitation	meters/yr	1	*default value*
Irrigation	meters/yr	0	assume for Hanford Sands (default was 0.2)
Irrigation mode (overhead or ditch?)		overhead	*default value*
Runoff coefficient		0	assume for Hanford Sands (default was 0.2)
Watershed area for nearby stream or pond	square meters	1,000,000	*default value*
Accuracy for water/soil computations		0.001	*default value*

Table 3-3. RESRAD Key Input Parameters and Values for Well Driller. (5 sheets)

RESRAD v 6.3; Pathways = soil ingestion, inhalation of particulates, inhalation of radon			
	UNITS	**VALUE**	**COMMENTS**
SATURATED ZONE			**Saturated Zone = Ringold**
Density of saturated zone	grams/cm^3	1.5	*default value*
Saturated zone total porosity		0.33	Ringold value
Saturated zone effective porosity		0.18	Ringold value
Saturated zone field capacity		0.21	Ringold value
Saturated zone hydraulic conductivity	meters/yr	7,300	Ringold value = 7,300 m/yr
Saturated zone hydraulic gradient		0.002	Ringold value
Saturated zone b parameter		4.05	RESRAD value for sand from Appendix E
Water table drop rate	meters/yr	0.2	Ringold value
Well pump intake depth	m below water table	10	*default value*
Model for water transport parameters (nondispersion or mass-balance)		nondispersion	*default value*
Well pumping rate	cubic meters/yr	30,000	10-20 gal/min or approx. 20,000–40,000 cubic meters/yr
UNSATURATED			**Unsaturated Zones = Hanford Sands, CCU, and Ringold**
Number of unsaturated zones	**3**		number of zones set manually
Unsaturated Zone #1	Hanford Sands		
Thickness	meters	33.5	110 ft; 33.5 m
Density	grams/cm^3	1.85	Hanford Sands = 1.4–2.3; WHC-EP-0883, Appendix A
Total porosity		0.3	Hanford Sands value; WHC-EP-0883, Appendix A
Effective porosity		0.25	Hanford Sands value; WHC-EP-0883, Appendix A
Field capacity		0.25	Hanford Sands value; WHC-EP-0883, Appendix A
Hydraulic conductivity	meters/yr	1,577	Hanford Sands = 0.005 cm/s; 1,577 m/yr; WHC-EP-0883, Appendix A
b parameter		4.05	RESRAD value for sand from Appendix E; Table E.2

Table 3-3. RESRAD Key Input Parameters and Values for Well Driller. (5 sheets)

RESRAD v 6.3; Pathways = soil ingestion, inhalation of particulates, inhalation of radon			
	UNITS	**VALUE**	**COMMENTS**
Unsaturated Zone #2	CCU (silt values; ignored caliche for model)		
Thickness	meters	3.1	10 ft; 3.1 m
Density	grams/cm^3	2.0	CCU (silt) value; WHC-EP-0883, Appendix A
Total porosity		0.37	CCU (silt) value; WHC-EP-0883, Appendix A
Effective porosity		0.29	CCU (silt) value; WHC-EP-0883, Appendix A
Field capacity		0.29	CCU (silt) value; WHC-EP-0883, Appendix A
Hydraulic conductivity	meters/yr	2,740	CCU value = 8.69E-03 cm/sec; 2,740 m/yr; WHC-EP-0883, Appendix A
b parameter		5.3	RESRAD value for silty loam from Appendix E; Table E.2
Unsaturated Zone #3	Ringold		
Thickness	meters	32.3	106 ft; 32.3 m
Density	grams/cm^3	1.85	Ringold = 1.4–2.3; WHC-EP-0883, Appendix A
Total porosity		0.22	Ringold value; WHC-EP-0883, Appendix A
Effective porosity		0.13	Ringold value; WHC-EP-0883, Appendix A
Field capacity		0.13	Ringold value; WHC-EP-0883, Appendix A
Hydraulic conductivity	meters/yr	7,300	Ringold = 7,300 m/yr; WHC-EP-0883, Appendix A
b parameter		4.05	RESRAD value for sand from Appendix E; Table E.2
OCCUPANCY			
Inhalation rate	m^3/yr	100	Assumes 20 m^3/day for 5 days/yr
Mass loading for Inhalation	g/m^3	3.70E-07	Site-specific based on a PEF of 2.72E+09
Exposure duration	years	1	Standard exposure duration for construction workers (EPA, 2002)
Indoor dust filtration factor		0	Receptors will spend all of their time outdoors
External gamma shielding factor		greyed out	Not pertinent to soil ingestion, inhalation of particulates, or inhalation of radon routes of exposure
Indoor time fraction		0	Receptors will spend all of their time outdoors
Outdoor time fraction		1	Receptors will spend all of their time outdoors
Shape of contaminated zone		circular	*default*

Table 3-3. RESRAD Key Input Parameters and Values for Well Driller. (5 sheets)

RESRAD v 6.3; Pathways = soil ingestion, inhalation of particulates, inhalation of radon			
	UNITS	VALUE	COMMENTS
INGESTION–Dietary			
Soil ingestion	g/yr	0.5	Assumes 0.1 g/day for construction workers (EPA, 2002) for 5 days/yr
Household water		0	Set to zero because receptor is not exposed to household water
INGESTION–NON DIETARY			
Depth of soil mixing layer	m	0.15	*default value*
Groundwater fractional usage (balance from surface water)–drinking water		0	Set to zero because receptor is not exposed to household water
Radon Data			
Cover total porosity		0	Set to zero because cover depth is zero
Cover volumetric water content		0	Set to zero because cover depth is zero
Cover radon diffusion coefficient	m^2/sec	0	Set to zero because cover depth is zero
Bldg foundation thickness	meters	0	Set to zero because time indoors is zero
Bldg foundation density	g/cm^3	0	Set to zero because time indoors is zero
Bldg foundation total porosity		0.0001	Set to zero because time indoors is zero
Bldg foundation volumetric water content		0	Set to zero because time indoors is zero
Bldg foundation radon diffusion coefficient	m^2/sec	0	Set to zero because time indoors is zero
Contaminated radon diffusion coefficient	m^2/sec	0.000002	*default value*
Radon vertical dimension of mixing	meters	2	*default value*
Building air exchange rate	1/hr	0	Set to zero because time indoors is zero
Building room height	meters	0.001	Set to small number because time indoors is zero
Building indoor area factor		0	Set to zero because time indoors is zero
Foundation depth below ground surface	meters	-1	*default value*
Ra-222 emanation coefficient		0.25	*default value*
Ra-222 emanation coefficient		0.15	*default value*
Storage Times	**greyed out**		
C-14			**For Site A-8 only**
Concentration in local water	g/cm^3	0.00002	*default value*
Concentration in contaminated soil	g/g	0.03	*default value*
Fraction of vegetation in carbon absorbed from soil		0.02	*default value*
Fraction of vegetation in carbon absorbed from air		0.98	*default value*

Table 3-3. RESRAD Key Input Parameters and Values for Well Driller. (5 sheets)

RESRAD v 6.3; Pathways = soil ingestion, inhalation of particulates, inhalation of radon			
	UNITS	**VALUE**	**COMMENTS**
Thickness of evasion layer of C-14 in soil	meters	0.3	*default value*
C-14 evasion flux rate from soil	1/sec	0.0000007	*default value*
C-12 evasion flux rate from soil	1/sec	1.00E-10	*default value*
Grain fraction in livestock feed (balance is hay/fodder)			*default value*
Beef cattle		0.8	*default value*
Milk cow		0.2	*default value*
DCF correction factor for gaseous forms of C-14		123.4	*default value*

Table 3-4. RESRAD Key Input Parameters and Values for Construction Worker. (4 sheets)

RESRAD v 6.3; Pathway = external radiation			
	UNITS	**VALUE**	**COMMENTS**
SOIL CONCENTRATIONS			
Basic radiation dose limit	mrem/yr	25	*default value*
Number of nuclides		varies	Depends on the site
Nuclide (#1)		varies	Depends on the site
Nuclide (#1) concentration	pCi/g		site-specific concentration set manually
Transport factors (for nuclide #1):	-----	-----	-----
Contaminated zone distribution coefficient	cm^3/g	varies	*chemical-specific*
Saturated zone distribution coefficient	cm^3/g	varies	*chemical-specific*
Number of Unsaturated Zones = 3	-----	-----	-----
Unsaturated zone 1 distribution coefficient	cm^3/g	varies	*chemical-specific*
Unsaturated zone 2 distribution coefficient	cm^3/g	varies	*chemical-specific*
Unsaturated zone 3 distribution coefficient	cm^3/g	varies	*chemical-specific*
Options:	-----	-----	-----
Water concentration: time since material placement	year	0	*default value*
Water concentration: groundwater concentration	pCi/L	greyed out (t=0)	*default value*
Solubility limit	mol/L	0	*default value*
Leach rate	/yr	0	*default value*
Use plant/soil ratio?	yes/no	no	*default value*
Nuclide (#2)		varies	Depends on the site
Nuclide (#2) concentration	pCi/g		site-specific concentration set manually
Transport factors (for nuclide #1):	-----	-----	-----
Contaminated zone distribution coefficient	cm^3/g	varies	*chemical-specific*
Saturated zone distribution coefficient	cm^3/g	varies	*chemical-specific*
Number of Unsaturated Zones = 3	-----	-----	-----
Unsaturated zone 1 distribution coefficient	cm^3/g	varies	*chemical-specific*
Unsaturated zone 2 distribution coefficient	cm^3/g	varies	*chemical-specific*
Unsaturated zone 3 distribution coefficient	cm^3/g	varies	*chemical-specific*
Options:	-----	-----	-----
Water concentration: time since material placement	year	0	*default value*

Table 3-4. RESRAD Key Input Parameters and Values for Construction Worker. (4 sheets)

RESRAD v 6.3; Pathway = external radiation			
	UNITS	**VALUE**	**COMMENTS**
Water concentration: groundwater concentration	pCi/L	greyed out (t=0)	*default value*
Solubility limit	mol/L	0	*default value*
Leach rate	/yr	0	*default value*
Use plant/soil ratio?	yes/no	no	*default value*
CALCULATION TIMES			
1	years	0	site-specific
2	years	17	site-specific
3	years	28	site-specific
4	years	150	site-specific
5	years	500	site-specific
6	years	1,000	site-specific
CONTAMINATED ZONE PARAMETERS			
Area of contaminated zone	square meters	1,811.61 / 2.323 / 1,579.35	Site-specific for Z-1A / Z-8 / A-8
Thickness of contaminated zone	meters	28.04 / 5.79 / 18.14	Site-specific for Z-1A / Z-8 / A-8
Length parallel to aquifer flow	meters	greyed out	*default value*
COVER/HYDROL			**Contaminated Zone = Hanford Sands**
Cover depth	meters	0	*default value*
Density of cover material	grams/cm^3	greyed out	*default value*
Cover erosion rate	meters/yr	greyed out	*default value*
Density of contaminated zone	grams/cm^3	1.85	Hanford Sands = 1.4–2.3
Contaminated zone erosion rate	meters/yr	0.001	*default value*
Contaminated zone total porosity		0.3	Hanford Sands value
Contaminated zone field capacity		0.1	Hanford Sands value
Contaminated zone hydraulic conductivity	meters/yr	1,577	Hanford Sands = 0.005 cm/s; 1,577 m/yr
Contaminated zone b parameter		4.05	RESRAD value for sand from Appendix E
Humidity in air	grams/cm^3	greyed out	*default value*
Evapotranspiration coefficient		0.5	*default value*

Table 3-4. RESRAD Key Input Parameters and Values for Construction Worker. (4 sheets)

RESRAD v 6.3; Pathway = external radiation			
	UNITS	**VALUE**	**COMMENTS**
Wind speed	meters/s	3.4	site-specific
Precipitation	meters/yr	1	*default value*
Irrigation	meters/yr	0	assume for Hanford Sands (default was 0.2)
Irrigation mode (overhead or ditch?)		overhead	*default value*
Runoff coefficient		0	assume for Hanford Sands (default was 0.2)
Watershed area for nearby stream or pond	square meters	greyed out	*default value*
Accuracy for water/soil computations		greyed out	*default value*
SATURATED ZONE			**Saturated Zone = Ringold**
Density of saturated zone	grams/cm^3	greyed out	*default value*
Saturated zone total porosity		greyed out	*default value*
Saturated zone effective porosity		greyed out	*default value*
Saturated zone field capacity		greyed out	*default value*
Saturated zone hydraulic conductivity	meters/yr	greyed out	*default value*
Saturated zone hydraulic gradient		greyed out	*default value*
Saturated zone b parameter		greyed out	*default value*
Water table drop rate	meters/yr	greyed out	*default value*
Well pump intake depth	m below water table	greyed out	*default value*
Model for water transport parameters (nondispersion or mass-balance)		nondispersion	*default value*
Well pumping rate	cubic meters/yr	greyed out	*default value*
UNSATURATED			**Unsaturated Zones = Hanford Sands, CCU, and Ringold**
Number of unsaturated zones	greyed out		Not pertinent to external radiation route of exposure
Unsaturated Zone #1	greyed out		Not pertinent to external radiation route of exposure
Unsaturated Zone #2	greyed out		Not pertinent to external radiation route of exposure
Unsaturated Zone #3	greyed out		Not pertinent to external radiation route of exposure
OCCUPANCY			

Table 3-4. RESRAD Key Input Parameters and Values for Construction Worker. (4 sheets)

RESRAD v 6.3; Pathway = external radiation			
	UNITS	**VALUE**	**COMMENTS**
Inhalation rate	m^3/yr	greyed out	Not pertinent to external radiation route of exposure
Mass loading for inhalation	g/m^3	greyed out	Not pertinent to external radiation route of exposure
Indoor dust filtration rate		greyed out	Not pertinent to external radiation route of exposure
Exposure duration	years	1	Standard exposure duration for construction workers
External gamma shielding factor		0	Receptors will spend all of their time outdoors
Indoor time fraction		0	Receptors will spend all of their time outdoors
Outdoor time fraction		0.027	Used here to decrease exposure to external radiation from constant to 8 hr/day for 30 days/yr (8 hr/24 hours * 30 days/365 days = 0.027)
Shape of contaminated zone		circular	*default*
INGESTION–Dietary	**greyed out**		
INGESTION–NON DIETARY	**greyed out**		
Radon	**greyed out**		
Storage Times	**greyed out**		

Table 3-5. RESRAD Key Input Parameters and Values for Well Driller. (4 sheets)

RESRAD v 6.3; Pathway = external radiation			
	UNITS	**VALUE**	**COMMENTS**
SOIL CONCENTRATIONS			
Basic radiation dose limit	mrem/yr	25	*default value*
Number of nuclides		varies	Depends on the site
Nuclide (#1)		varies	Depends on the site
Nuclide (#1) concentration	pCi/g		site-specific concentration set manually
Transport factors (for nuclide #1):	-----	-----	-----
Contaminated zone distribution coefficient	cm^3/g	varies	*chemical-specific*
Saturated zone distribution coefficient	cm^3/g	varies	*chemical-specific*
Number of Unsaturated Zones = 3	-----	-----	-----
Unsaturated zone 1 distribution coefficient	cm^3/g	varies	*chemical-specific*
Unsaturated zone 2 distribution coefficient	cm^3/g	varies	*chemical-specific*
Unsaturated zone 3 distribution coefficient	cm^3/g	varies	*chemical-specific*
Options:	-----	-----	-----
Water concentration: time since material placement	year	0	*default value*
Water concentration: groundwater concentration	pCi/L	greyed out (t=0)	*default value*
Solubility limit	mol/L	0	*default value*
Leach rate	/yr	0	*default value*
Use plant/soil ratio?	yes/no	no	*default value*
Nuclide (#2)		varies	Depends on the site
Nuclide (#2) concentration	pCi/g		site-specific concentration set manually
Transport factors (for nuclide #1):	-----	-----	-----
Contaminated zone distribution coefficient	cm^3/g	varies	*chemical-specific*
Saturated zone distribution coefficient	cm^3/g	varies	*chemical-specific*
Number of Unsaturated Zones = 3	-----	-----	-----
Unsaturated zone 1 distribution coefficient	cm^3/g	varies	*chemical-specific*
Unsaturated zone 2 distribution coefficient	cm^3/g	varies	*chemical-specific*
Unsaturated zone 3 distribution coefficient	cm^3/g	varies	*chemical-specific*
Options:	-----	-----	-----
Water concentration: time since material placement	year	0	*default value*

Table 3-5. RESRAD Key Input Parameters and Values for Well Driller. (4 sheets)

RESRAD v 6.3; Pathway = external radiation			
	UNITS	**VALUE**	**COMMENTS**
Water concentration: groundwater concentration	pCi/L	greyed out (t=0)	*default value*
Solubility limit	mol/L	0	*default value*
Leach rate	/yr	0	*default value*
Use plant/soil ratio?	yes/no	no	*default value*
CALCULATION TIMES			
1	years	0	site-specific
2	years	17	site-specific
3	years	28	site-specific
4	years	150	site-specific
5	years	500	site-specific
6	years	1,000	site-specific
CONTAMINATED ZONE PARAMETERS			
Area of contaminated zone	square meters	80	Site-specific; well tailings spread over area (p. 21, Rittman, 2004)
Thickness of contaminated zone	meters	0.05	Site-specific; layer of contaminated soil surrounding driller (p. 21, Rittman, 2004)
Length parallel to aquifer flow	meters	greyed out	*default value*
COVER/HYDROL			**Contaminated Zone = Hanford Sands**
Cover depth	meters	0	*default value*
Density of cover material	grams/cm^3	greyed out	*default value*
Cover erosion rate	meters/yr	greyed out	*default value*
Density of contaminated zone	grams/cm^3	1.85	Hanford Sands = 1.4–2.3
Contaminated zone erosion rate	meters/yr	0	Set to zero
Contaminated zone total porosity		0.3	Hanford Sands value
Contaminated zone field capacity		0.1	Hanford Sands value
Contaminated zone hydraulic conductivity	meters/yr	1,577	Hanford Sands = 0.005 cm/s; 1,577 m/yr
Contaminated zone b parameter		4.05	RESRAD value for sand from Appendix E
Humidity in air	grams/cm^3	greyed out	*default value*
Evapotranspiration coefficient		0.5	*default value*
Wind speed	meters/s	3.4	site-specific

Table 3-5. RESRAD Key Input Parameters and Values for Well Driller. (4 sheets)

RESRAD v 6.3; Pathway = external radiation			
	UNITS	**VALUE**	**COMMENTS**
Precipitation	meters/yr	1	*default value*
Irrigation	meters/yr	0	assume for Hanford Sands (default was 0.2)
Irrigation mode (overhead or ditch?)		overhead	*default value*
Runoff coefficient		0	assume for Hanford Sands (default was 0.2)
Watershed area for nearby stream or pond	square meters	greyed out	*default value*
Accuracy for water/soil computations		greyed out	*default value*
SATURATED ZONE			**Saturated Zone = Ringold**
Density of saturated zone	grams/cm^3	greyed out	*default value*
Saturated zone total porosity		greyed out	*default value*
Saturated zone effective porosity		greyed out	*default value*
Saturated zone field capacity		greyed out	*default value*
Saturated zone hydraulic conductivity	meters/yr	greyed out	*default value*
Saturated zone hydraulic gradient		greyed out	*default value*
Saturated zone b parameter		greyed out	*default value*
Water table drop rate	meters/yr	greyed out	*default value*
Well pump intake depth	m below water table	greyed out	*default value*
Model for water transport parameters (nondispersion or mass-balance)		nondispersion	*default value*
Well pumping rate	cubic meters/yr	greyed out	*default value*
UNSATURATED			**Unsaturated Zones = Hanford Sands, CCU, and Ringold**
Number of unsaturated zones	greyed out		Not pertinent to external radiation route of exposure
Unsaturated Zone #1	greyed out		Not pertinent to external radiation route of exposure
Unsaturated Zone #2	greyed out		Not pertinent to external radiation route of exposure
Unsaturated Zone #3	greyed out		Not pertinent to external radiation route of exposure
OCCUPANCY			
Inhalation rate	m^3/yr	greyed out	Not pertinent to external radiation route of exposure
Mass loading for inhalation	g/m^3	greyed out	Not pertinent to external radiation route of exposure
Indoor dust filtration rate		greyed out	Not pertinent to external radiation route of exposure

Table 3-5. RESRAD Key Input Parameters and Values for Well Driller. (4 sheets)

RESRAD v 6.3; Pathway = external radiation			
	UNITS	**VALUE**	**COMMENTS**
Exposure duration	years	1	Standard exposure duration for construction workers
External gamma shielding factor		0	Receptors will spend all of their time outdoors
Indoor time fraction		0	Receptors will spend all of their time outdoors
Outdoor time fraction		0.00457	Used here to decrease exposure to external radiation from constant to 8 hr/day for 5 days/yr (8 hr/24 hours * 5 days/365 days = 0.00457)
Shape of contaminated zone		circular	*default*
INGESTION–Dietary	**greyed out**		
INGESTION–NON DIETARY	**greyed out**		
Radon	**greyed out**		
Storage Times	**greyed out**		
C-14			**For Site A-8 only**
Concentration in local water	g/cm^3	0.00002	*default value*
Concentration in contaminated soil	g/g	0.03	*default value*
Fraction of vegetation in carbon absorbed from soil		0.02	*default value*
Fraction of vegetation in carbon absorbed from air		0.98	*default value*
Thickness of evasion layer of C-14 in soil	meters	0.3	*default value*
C-14 evasion flux rate from soil	1/sec	0.0000007	*default value*
C-12 evasion flux rate from soil	1/sec	1.00E-10	*default value*
Grain fraction in livestock feed (balance is hay/fodder)			*default value*
Beef cattle		0.8	*default value*
Milk cow		0.2	*default value*
DCF correction factor for gaseous forms of C-14		123.4	*default value*

Table 3-6. Site-Specific RESRAD Input Parameters for the Soil Sites.

Site Name	Original Site Area (ft)	Radioactive Contamination: Area (ft)	Radioactive Contamination: ft^2 (m^2)	Radioactive Contamination: Depth (ft bgs)	Rad Waste Thickness (ft)	Depth to Groundwater (ft bgs)	Reference
216-Z-1A Tile Field[a]	260 x 100 x 6	260 x 100	26,000 (2,415.5)	6 to 100	94 (28.65 m)	234 (71 m)	p. 1-14, Fig 1-6, 3-23, Fig 3-17 (DOE/RL-2006-51)
216-Z-8 French Drain[b]	5 x 5 x 16	5 x 5	25 (2.323)	16 to 35	19 (5.79 m)	223 (68 m)	p. 7, 33, 34, 35 (RHO-RE-EV-46 P)
216-Z-9 Trench[c]	120 x 90 x 20	120 x 90	10,800 (1,003.35)	21 to 120	99 (30.18 m)	223 (68 m)	p. 1-11, 1-22, 3-9, 3-45 (DOE/RL-2006-51)
216-Z-10 Injection/Reverse Well[d]	3 wells, 175 bgs	No Pu found in area near 231-W-150 reverse well		NA	NA	250 (76.2 m)	p. 29 (Brown and Ruppert, 1948)
216-A-8 Crib[e]	850 x 20 x 8.5 to 11.5	850 x 20	17,000 (1,579.35)	10.5 to 70	59.5 (18.14 m)	262 (80 m)	p. 1-15, 1-27, 3-39, 3-75 (DOE/RL-2006-51)

[a]Thickness is between 6 to 100 ft bgs, which is based on the depth of distribution pipe to where concentrations are at background or below a screening value; available analytical data is from 4.92 to 153.5 ft bgs.

[b]The RI states thickness is between 16 to 35 ft bgs; available analytical data is from 17 to 35 ft bgs.

[c]The concrete cover is 120 x 90 and the base of trench is 60 x 30. In the 1970s, 1 ft of soil was removed from trench bottom. Thickness is between 21 to 120 ft bgs based on bottom of trench to where concentrations are at background or below a screening value; available analytical data is from 47.5 to 133 ft bgs.

[d]Z-10 = the three soil borings 15 ft from the well did not find plutonium.

[e]In 1990, 2 feet of cover was added to original depth and is included in the thickness. Thickness is between 10.5 to 70 ft bgs based on bottom of crib to where concentrations are at background or below a screening value; available analytical data is from 19 to 264.5 ft bgs.

APPENDIX A

ATTACHMENT 4

DEFAULT EXPOSURE FACTORS

The following default exposure factors were used in the risk assessment for the 200-ZP-1 Groundwater OU and the representative soil waste sites. Site-specific exposure factors are discussed in Section A3.3 of the HHRA (Appendix A).

CONSTRUCTION WORKER EXPOSURE FACTORS
(Exposures to Soil)

Body Weight. An adult body weight of 70 kg was used. This is the average body weight for adult men and women combined, rounded to 70 kg (EPA 540/1-89/002).

Inhalation Rate. The recommended construction worker inhalation rate of 20 m^3/day was selected for soil exposure (OSWER Directive 9355.4-24). According to the *Exposure Factors Handbook* (EPA/600/P-95-002Fa), an inhalation rate for adults engaged in light activities is 1 m^3/hr, 1.6 m^3/hr for those engaged in moderate activities, and a rate of 2.5 m^3/hr for those engaged in heavy activities outdoors. In a construction scenario, this value of 20 m^3/day equates to an inhalation rate of 2.5 m^3/hr for 8 hr/day, which is likely an overestimate. For example, while the definitions of heavy activities are somewhat subjective, the *Exposure Factors Handbook* states that representative "heavy" activities include vigorous physical exercise (i.e., fast running) and climbing stairs carrying a load.

Soil Ingestion Rate. An RME soil ingestion rate of 330 mg/day for a construction worker was selected as recommended in the *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (OSWER Directive 9355.4-24). This value is the upper-percentile adult ingestion rate from a soil ingestion mass-balance study conducted by Stanek et al. (1997) of adults engaged in routine day-to-day activities over a 4-week period. However, this estimate, as stated by the authors, is highly uncertain due to the small size of the study.

Skin Surface Area. For construction workers, an exposed skin surface area of 3,300 cm^2 was used as recommended in EPA's *Supplemental Guidance for Developing Soil Screening Levels at Superfund Sites* (OSWER Directive 9355.4-24). This corresponds to exposure to head, forearms, and hands.

Adherence Factor. A soil-to-skin adherence factor of 0.3 mg/cm^2-event was used for the construction worker soil exposure scenario (EPA, 2004). This value in the EPA's soil screening guidance is based on studies (i.e., Kissel et al., 1996, Kissel et al., 1998; and Holmes et al., 1999, as cited in OSWER Directive 9355.4-24) where data suggest that (1) soil properties influence adherence, (2) soil adherence varies considerably across different parts of the body, and (3) soil adherence varies with activity (OSWER Directive 9355.4-24). The adherence factor of 0.3 mg/cm^2 represents the 95^{th} percentile for construction workers.

Averaging Time. For carcinogens, an averaging time of 70 years (equivalent to a lifetime), or 25,550 days, was used (EPA 540/1-89-002). For noncarcinogens, an averaging time equal to the exposure duration (1 year, or 365 days, for construction worker) was used (EPA 540/1-89-002).

RESIDENTIAL FARMER EXPOSURE FACTORS
(Exposures to Soil, Tap Water, Irrigation Water, Homegrown Produce, and Livestock)

Adherence Factor. Although children will have a smaller total skin surface area exposed than adult receptors, they are assumed to have a much higher soil to skin adherence factor. Recent data provide evidence to demonstrate that (1) soil properties influence adherence, (2) soil adherence varies considerably across different parts of the body, and (3) soil adherence varies with activity (Kissel et al., 1996; Kissel et al., 1998; and Holmes et al., 1999, as cited in OSWER Directive 9355.4-24). Because children are assumed to have additional, more sensitive body parts exposed (e.g., feet) and to engage in higher soil contact activities (e.g., playing in wet soil), OSWER Directive 9355.4-24 recommends the use of a body part-weighted adherence factor of 0.2 for children and 0.07 for adults in residential exposure scenarios.

Averaging Time. For carcinogens, an averaging time of 70 years (equivalent to a lifetime), or 25,550 days, was used (EPA 540/1-89-002). For noncarcinogens, an averaging time is equal to the exposure duration multiplied by 365 days, or 2,190 days for children and 8,760 days for adults (EPA 540/1-89-002).

Body Weight. An adult body weight of 70 kg was assumed. This is the average body weight for adult men and women combined, rounded to 70 kg (OSWER Directive 9285.6-03). For children aged 0 to 6 years, an average body weight of 15 kg was assumed (OSWER Directive 9385.6-03).

Exposure Duration. For evaluation of the residential exposures to soil, an exposure duration of 30 years was assumed. This represents the 90^{th} percentile for time spent at one residence (OSWER Directive 9385.6-03). Of the 30 years of total exposure duration, ages 0 to 6 years accounts for the period of lowest body weight. A 24-year duration was assessed for older children and adults (OSWER Directive 9385.6-03).

Exposure Frequency. The EPA default residential exposure frequency of 350 days/yr was used (OSWER Directive 9385.6-03). This value assumes that 2 weeks of vacation per year will be spent out of the residence.

Ingestion Rate of Soil. An RME soil ingestion rate of 200 mg/day for a child and 100 mg/day for an adult, as recommended in the *Supplemental Guidance for Developing Soil Screening Levels* for Superfund sites (OSWER Directive 9355.4-24). A number of studies have shown that inadvertent ingestion of soil is common among children age 6 and younger (Calabrese et al., 1989; Davis et al., 1990; and Van Wijnen et al., 1990, as cited in OSWER Directive 9355.4-24). Exposure is higher during childhood and decreases with age (OSWER Directive 9355.4-24).

Ingestion Rate of Water. A groundwater ingestion rate of 1 L/day for children and 2 L/day for adults was selected as recommended by the *Exposure Factors Handbook* (EPA/600/P-95-002Fa). The 2 L/day corresponds to the 84^{th} percentile of the intake rate distribution among adults in the Ershow and Cantor (1989) study.

Inhalation Rate. The mean inhalation rate of 10 m^3/day was selected for children (ages 6 to 8 years) exposure to groundwater (EPA/600/P-95-002Fa). The recommended inhalation rate of 20 m^3/day was selected for adult exposure to groundwater (OSWER Directive 9355.4-24). According to the *Exposure Factors Handbook* (EPA/600/P-95-002Fa), an inhalation rate for adults engaged in light activities is 1 m^3/hr, 1.6 m^3/hr for those engaged in moderate activities, and a rate of 2.5 m^3/hr for those engaged in heavy activities outdoors. In a residential scenario, this value of 20 m^3/day equates to an inhalation rate of 2.5 m^3/hr for 8 hr/day, which is likely an overestimate. For example, while the definitions of heavy activities are somewhat subjective, the *Exposure Factors Handbook* states representative "heavy" activities include vigorous physical exercise (i.e., fast running) and climbing stairs carrying a load.

Skin Surface Area. For residential exposures to tap water, surface area values for children and adults represent the median (50th percentile) values from the *Exposure Factors Handbook* (EPA/600/P-95-002Fa). Children have 6,600 cm^2 and adults have 18,000 cm^2 of exposed total skin surface area (EPA, 2004). The residential scenario assumes dermal contact while bathing or showering, thus, total skin surface values are used.

For residential exposures to soil, children are assumed to have 2,800 cm^2 of exposed skin surface area (face, forearms, hands, lower legs, and feet), while adults are assumed to have 5,700 cm^2 exposed (face, forearms, hands, and lower legs [OSWER Directive 9355.4-24]). These surface area values represent the median (50th percentile) values for all children and adults (EPA/600/P-95-002Fa).

Volatilization Factor for Water. The volatilization factor is 0.5 L/m^3 for volatile chemicals only. The number was derived by Andelman (1990), as cited in *Supplemental Risk Assessment Guidance for Superfund* (EPA, 1991). It is assumed that the transfer efficiency weighted by water use is 50 percent (i.e., half of the concentration of each chemical in water will be transferred into air by all water uses).

WELL DRILLER EXPOSURE FACTORS
(Exposures to Soil)

Body Weight. An adult body weight of 70 kg was used. This is the average body weight for adult men and women combined, rounded to 70 kg (EPA 540/1-89/002).

Inhalation Rate. The recommended construction worker inhalation rate of 20 m^3/day was selected for well driller exposures to soil (OSWER Directive 9355.4-24). According to the *Exposure Factors Handbook* (EPA/600/P-95-002Fa), an inhalation rate for adults engaged in light activities is 1 m^3/hr, 1.6 m^3/hr for those engaged in moderate activities, and a rate 2.5 m^3/hr for those engaged in heavy activities outdoors. In a construction scenario, this value of 20 m^3/day equates to an inhalation rate of 2.5 m^3/hr for 8 hr/day, which is likely an overestimate. For example, while the definitions of heavy activities are somewhat subjective, EPA/600/P-95-002Fa) states representative "heavy" activities include vigorous physical exercise (i.e., fast running) and climbing stairs carrying a load.

Soil Ingestion Rate. The EPA default occupational soil ingestion rate of 100 mg/day was used (OSWER Directive 9355.4-24) to evaluate well driller exposures to soil

Skin Surface Area. For well drillers, an exposed skin surface area of 3,300 cm^2 was used as recommended in EPA's *Supplemental Guidance for Developing Soil Screening Levels* for Superfund Sites (OSWER Directive 9355.4-24); this corresponds to exposure to head, forearms, and hands. This is the same default factor recommended for construction worker exposures.

Adherence Factor. A soil adherence factor of 0.2 was assumed for well drillers. This is EPA's default adherence factor for commercial/industrial adult worker (OSWER Directive 9355.4-24; EPA, 2004). This value is based on the 50th percentile weighted adherence factors for utility workers (EPA, 2004).

Averaging Time. For carcinogens, an averaging time of 70 years (equivalent to a lifetime), or 25,550 days, was used (EPA 540/1-89/002). For noncarcinogens, an averaging time equal to the exposure duration (5 days) was used (EPA 540/1-89/002).

INDUSTRIAL EXPOSURE FACTORS
(Exposures to Tap Water)

Body Weight. An adult body weight of 70 kg was used. This is the average body weight for adult men and women combined, rounded to 70 kg (EPA 540/1-89/002).

Inhalation Rate. An inhalation rate of 1.5 m^3/hr was selected to evaluate industrial worker exposures to tap water. The value corresponds to an inhalation rate for those engaged in moderate activities (EPA/600/P-95-002FA).

Ingestion Rate. The EPA default occupational tap water ingestion rate of 1 L/day was used for the industrial worker scenarios (OSWER Directive 9285.6-03).

Exposure Duration. An industrial worker was conservatively assumed to work for 25 years in the same area; this represents the 95th percentile for length of time that employees work in the same location, according to the Bureau of Labor Statistics (as cited in OSWER Directive 9285.6-03).

Exposure Frequency. The default RME occupational exposure frequency of 250 days/yr was used (OSWER Directive 9285.6-03) for civilian building workers. This is based on a 5-day workweek with 2 weeks of vacation a year.

Averaging Time. For carcinogens, an averaging time of 70 years (equivalent to a lifetime), or 25,550 days, was used (EPA 540/1-89/002). For noncarcinogens, an averaging time equal to the exposure duration (25 years or 9,125 days) was used (EPA 540/1-89/002).

Volatilization Factor for Water. The volatilization factor is 0.5 L/m^3 for volatile chemicals only. The number was derived by Andelman (1990), as cited in EPA (1991). It is assumed that the transfer efficiency weighted by water use is 50 percent (i.e., half of the concentration of each chemical in water will be transferred into air by all water uses).

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APPENDIX A

ATTACHMENT 5

TOXICITY PROFILES FOR EACH CONTAMINANT OF POTENTIAL CONCERN

ATTACHMENT 5
TABLE OF CONTENTS

1,2-DIBROMO-3-CHLOROPROPANE

1,2-dibromo-3-chloropropane is a manufactured chemical used in combination with other chemicals to create materials that resist burning. It has also been used in the past as a pesticide on farms. This practice was outlawed in the U.S. in 1979, except Hawaii (1985). 1,2-dibromo-3-chloropropane typically enters the environment via the air or as a surface water spill that quickly evaporates. 1,2-dibromo-3-chloropropane has been shown to persist in the air for several months before it is completely broken down (ATSDR, 2006). Exposure to 1,2-dibromo-3-chloropropane by inhalation has been shown to reduce a male's ability to reproduce by lowering sperm counts (ATSDR, 2006). Occupational inhalation exposures have been shown to cause headaches, nausea, lightheadedness, and weakness in workers. Studies involving test animals have shown that exposure to this chemical can cause nose cancer from inhalation, stomach and kidney cancers from ingestion, as well as stomach and skin cancer from dermal contact (ATSDR, 2006). A clear link to human toxicological effects was not made by these studies.

Toxic Effects

Testicular effects for humans are associated with inhalation of 1,2-dibromo-3-chloropropane in occupational settings. No chronic oral RfD for 1,2-dibromo-3-chloropropane in IRIS is available at this time (EPA, 2007). The NOAEL RfC for inhalation is 0.94 mg/m^3 (0.1 ppm) (EPA, 2007). The EPA's provisional chronic oral RfD of 2×10^{-4} was used in calculation and obtained from Region 6 HHSLs (EPA, 2006). Further studies involving rabbit populations developed LOAEL that is an order of magnitude higher than the NOAEL (9.4 mg/m^3, or 1 ppm) (EPA, 2007). No studies have been issued assessing possible respiratory tract effects of 1,2-dibromo-3-chloropropane exposure. The oral cancer slope factor for 2-dibromo-3-chloropropane is 0.8 per mg/kg-day and the inhalation cancer slope factor is 21 per mg/kg-day (EPA, 2006).

Carcinogenicity

The carcinogenicity of 1,2-dibromo-3-chloropropane is not available at this time.

References

ATSDR, 2006, *Toxicological Profile for 1,2-Dibromo-3-chloropropane, Update*, dated March 2006, U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Washington, D.C.

EPA, 2006, *EPA Region 6 Human Health Medium-Specific Screening Levels 2007 and Supplemental Information*, dated December 14, 2006, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 2007, *Integrated Risk Information System (IRIS) Online Database*, accessed in April 2007, http://www.epa.gov/iris/index.html, U.S. Environmental Protection Agency, Washington, D.C.

AMERICIUM-241

Americium is a human-made radioactive element. There are no naturally occurring or stable isotopes of americium. The two major isotopes of americium are americium-241 and americium-243, both of which have the same chemical behavior in the environment. These two isotopes emit alpha particles and gamma rays to decay into neptunium isotopes, neptunium-237 and neptunium-239, which are also radioactive isotopes. The half-life of americium-241 is 432 years, and the half-life of americium-243 is 7,370 years (ATSDR, 2004).

The primary concern for exposure to americium is the risk of exposure to ionizing alpha and gamma radiation. Ionizing radiation has been shown to be a human carcinogen, and EPA classifies all radionuclides as Group A carcinogens (EPA, 2001). Based on the carcinogenicity of ionizing radiation, cancer slope factors have been derived for americium isotopes. The oral slope factor for americium-241 is 2.17×10^{-10} risk per pCi for soil ingestion, 2.81×10^{-8} risk per pCi for inhalation, and 2.76×10^{-8} risk per pCi for external effects.

Information on adverse human health effects is mainly limited to a single case report of an individual accidentally exposed to high levels of americium that resulted in a significant internal dose. In this case, adverse effects of lymphopenia, thrombocytopenia, and histological signs of bone marrow peritrabecular fibrosis, bone cell depletion, and bone marrow atrophy were noted. These data are supported by findings in laboratory animals exposed to large does of americium in which degenerative changes in bone, liver, kidneys, and thyroid have been observed following ingestion and inhalation exposure. Increases in bone cancer have been observed in animal studies. Information on the dermal absorption of americium in humans or animals is extremely limited. At very high doses of americium, there is an increased risk for gamma radiation to cause dermal and subdermal effects such as erythema, ulceration, or even tissue necrosis. All of these adverse effects have been attributed to the ionizing radiation of americium. No non-ionizing radiation effects of americium were identified (ATSDR, 2004). In the absence of relevant data, provisional non-cancer risk assessment values based on americium-induced effects that are not attributable to ionizing radiation have not been derived.

References

ATSDR, 2004, *Toxicological Profile for Americium*, U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Washington, D.C.

EPA, 2001, *Update of Radionuclide Toxicity of the Health Effects Assessment Summary Tables (HEAST)*, dated April 16, 2001, U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C.

CADMIUM

Cadmium is obtained mainly as a byproduct during the processing of zinc-bearing ores and also from the refining of lead and copper from sulfide ores. Cadmium is used primarily for the production of nickel-cadmium batteries, in metal plating, and for the production of pigments, plastics, synthetics, and metallic alloys. Cadmium has been shown to be toxic to human populations from occupational inhalation exposure and accidental ingestion of cadmium-contaminated food. Inhalation of cadmium dust in certain occupational settings may be associated with an increased incidence of lung cancer. Ingestion of elevated levels of cadmium has resulted in toxicity to the kidney and skeletal system and may be associated with an elevated incidence of hypertension and cardiovascular disease.

Cadmium is poorly absorbed from the lung, gastrointestinal tract, and skin. Individuals with dietary deficiencies of iron, calcium, or protein exhibit higher absorption of ingested cadmium. The issue of cadmium bioavailability is especially important at mining, milling, and smelting sites because the cadmium at these sites often exists, at least in part, as a poorly soluble sulfide and may also occur in particles of inert or insoluble material. These factors all tend to reduce the bioavailability of cadmium in soil. Cadmium in the body binds readily to certain sulfur-containing proteins, such as metallothionein. Binding to metallothionein is thought to reduce the toxicity of cadmium. Following ingestion, fecal excretion is high due to poor gastrointestinal absorption; most cadmium that has been absorbed, however, is excreted very slowly, with fecal and urinary excretion being about equal. Urinary cadmium levels are an indicator of body burden.

Toxic Effects

Much of the understanding about cadmium toxicity in humans is based on epidemiological studies of human populations. Humans consuming cadmium-contaminated rice in Japan developed kidney and skeletal system effects. Inhalation of cadmium in occupational settings has also been associated with kidney toxicity. There is conflicting evidence as to whether or not cadmium exposure produces cardiovascular effects or hypertension in humans; factors such as cigarette smoking are confounders in determining the relationship between cadmium exposure and cardiovascular effects. Excessive cadmium ingestion exposure in combination with a low dietary intake of iron may be associated with anemia.

Populations potentially sensitive to cadmium have not been studied systematically; however, it is possible to infer potential sensitivities based on the available data. Individuals with poor nutritional status, particularly in terms of iron and calcium, may absorb more cadmium from the gastrointestinal tract. Individuals with preexisting kidney damage may experience kidney toxicity at cadmium doses lower than the dose that would be toxic for normal individuals.

The EPA recently conducted a toxicological review of cadmium and compounds in support of a proposed revision of the toxicity factors currently listed in the IRIS database. However, the report is currently undergoing external review and the proposed toxicity factors have not been finalized.

The current EPA recommendation consists of two oral RfDs for cadmium, one for cadmium exposure from food, and one for cadmium exposure from water. Both RfDs recognize that a concentration of 200 μg/g (wet-weight) in the human kidney cortex is the highest renal level not associated with significant proteinuria. A toxicokinetic model was used by the EPA to determine the level of chronic human oral exposure (NOAEL) that results in the critical concentration of cadmium in the kidney of 200 µg/g; the model assumes that 0.01 percent of the cadmium body burden is eliminated per day (EPA, 1985). Assuming 2.5 percent absorption of cadmium from food or 5 percent from water, the toxicokinetic model predicts that the NOAEL for chronic cadmium exposure is 0.005 and 0.01 mg/kg-day from water and food, respectively (i.e., the doses corresponding to the 200 µg/g critical kidney concentration). An uncertainty factor of 10 to account for intrahuman variability was applied to these NOAELs to obtain an RfD of 0.0005 mg/kg-day (water) and an RfD of 0.001 mg/kg-day (food) (EPA, 2007). No inhalation RfD or RfC is currently listed for cadmium. A dermal RfD of 0.001 mg/kg-day multiplied by 2.5 percent (0.000025 mg/kg-day) was selected for use in the calculations, as recommended by EPA (EPA, 2004). The critical toxic effect proposed for both the oral RfD and inhalation RfC is renal dysfunction, as indicated by minimal proteinuria/enzymuria.

Carcinogenicity

Cadmium is widely thought to be a possible carcinogen via the inhalation route (lung cancer); however there are few studies to evaluate whether ingested cadmium is carcinogenic in humans. Studies in laboratory animals generally do not indicate that cadmium is carcinogenic by ingestion. Inhaled cadmium is carcinogenic to laboratory animals and there is also some human data linking cadmium inhalation and lung cancer; however, epidemiological studies of cadmium-exposed workers have been inconclusive in demonstrating the carcinogenicity of inhaled cadmium. The EPA has classified cadmium as a probable human carcinogen by inhalation (Group B1) based on limited evidence in humans and sufficient evidence in laboratory animals. The EPA's (2007) inhalation slope factor is 6.3 $(mg/kg\text{-}day)^{-1}$ based on human lung, trachea, and bronchus cancer deaths in workplace exposures.

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CARBON-14

A naturally occurring radioactive isotope of carbon, carbon-14 is found at low concentrations in all carbon. Carbon-14 emits beta particles as it decays and has a half-life of 5,700 years (ANL, 2007).

The primary concern for exposure to carbon-14 is the risk of exposure to ionizing radiation from beta particles. Ionizing radiation has been shown to be a human carcinogen, and EPA classifies all radionuclides as Group A carcinogens (EPA, 2001). Based on the carcinogenicity of ionizing radiation, cancer slope factors have been derived for carbon isotope 14. The oral slope factor for carbon-14 is 2.79×10^{-12} risk per pCi for soil ingestion, 7.07×10^{-12} risk per pCi for inhalation, and 7.83×10^{-12} risk per pCi for external effects.

Although the radiation energy of carbon-14 is quite low, this isotope does have the potential to induce cancer through radiation. Since carbon-14 does not emit gamma rays and the beta particle that it does emit cannot penetrate tissue deeply or travel far in air, the primary pathway of concern is ingestion. Once taken into the body, carbon may travel to any organ and has the potential to induce cancer. Carbon is an essential component of living tissue and no non-ionizing radiation effects of carbon-14 were identified. In the absence of relevant data, provisional non-cancer risk assessment values based on carbon-induced effects that are not attributable to ionizing radiation have not been derived.

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CARBON TETRACHLORIDE

Carbon tetrachloride is a solvent that has been used in the past as a cleaning fluid or degreasing agent in industrial applications. Although most uses have been discontinued, the possibility still exists for carbon tetrachloride to be released to the environment, primarily through industrial processes. Degradation of carbon tetrachloride occurs slowly in the environment, which contributes to the accumulation of the chemical in the atmosphere, as well as the groundwater. Carbon tetrachloride is widely dispersed and persistent in the environment but is not detected frequently in foods.

Because of carbon tetrachloride's widespread use in medical, industrial, and residential applications, there is a reasonable amount of toxicity information available. The principal toxic effects are on the liver, kidneys, and the central nervous system (ATSDR, 2005). Studies in animals, combined with limited observations in humans, indicate that the principal adverse health effects associated with inhalation exposure to carbon tetrachloride are central nervous system depression, liver damage, and kidney damage. Case reports in humans and studies in animals indicate that the liver, kidney, and central nervous system are also the primary targets of toxicity following oral exposure to carbon tetrachloride.

A number of well-conducted animal studies indicate that exposure to carbon tetrachloride produces liver tumors; however, data for humans is limited (EPA, 2007). Two kinds of processes appear to contribute to the carcinogenicity of carbon tetrachloride (*Guidelines for Carcinogen Risk Assessment* [EPA/630/P-03/001F]). Genotoxicity, primarily covalent binding to DNA in the liver, results from the direct binding of reactive carbon tetrachloride metabolites or lipid peroxidation products in animals exposed orally or by intraperitoneal injection. There is some evidence that carbon tetrachloride may also cause cancer by a nongenotoxic mechanism involving cellular regeneration (EPA/630/P-03/001F). The U.S. Department of Health and Human Services has determined that carbon tetrachloride may reasonably be anticipated to be a carcinogen. International Agency for Research on Cancer (IARC) has classified carbon tetrachloride in Group 2B, possibly carcinogenic to humans. The EPA has determined that carbon tetrachloride is a probable human carcinogen (EPA/630/P-03/001F).

The EPA has derived an oral slope factor for carbon tetrachloride of 0.13 $(mg/kg\text{-}day)^{-1}$ based on studies in rats, mice, and hamsters that exhibited increased incidence of liver tumors upon higher dose exposures (EPA, 2007). The geometric mean of the unit risks derived from four studies was used as the basis for the oral slope factor. According to EPA (2007), all four of the studies used were all deficient in some respect, precluding the choice of any one study as most appropriate. The EPA did not assign a confidence level to the derived slope factor. From these studies, EPA (2007) has also derived an inhalation slope factor for this chemical of 0.0525 $(mg/kg\text{-}day)^{-1}$. The EPA is currently working to revise the carcinogenicity assessment for carbon tetrachloride (ATSDR, 2005).

The EPA has established an oral RfD of 0.0007 mg/kg-day. The RfD is based on liver lesions in rats from a subchronic study and EPA has assigned an uncertainty factor of 1,000 to the RfD and listed their confidence in the value as medium. There is no RfC for this chemical; therefore, non-cancer inhalation effects were not evaluated in this assessment.

References

ATSDR, 2005, *Toxicological Profile for Carbon Tetrachloride*, dated August 2004, U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Washington, D.C.

EPA, 2007, *Integrated Risk Information System (IRIS) Online Database*, accessed in April 2007, http://www.epa.gov/iris/index.html, U.S. Environmental Protection Agency, Washington, D.C.

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CESIUM-137

Cesium is a naturally occurring element that is typically found in rocks, soil, and dust at low concentrations. Natural cesium is present in the environment in only one stable form, cesium-133. The two most important radioactive isotopes of cesium are cesium-134 and cesium-137. Each atom of cesium-137 decays into the stable isotope, barium-137, by emitting beta particles and gamma radiation (ATSDR, 2004). The half-life of cesium-137 is approximately 30 years.

Although inhalation exposure is possible, the most important exposure routes for radioisotopes of cesium are external exposure to the radiation released by the radioisotopes and ingestion of radioactive cesium-contaminated food sources. The primary concern for exposure to cesium is the risk of exposure to ionizing radiation from beta particles and gamma rays. Ionizing radiation has been shown to be a human carcinogen, and EPA classifies all radionuclides as Group A carcinogens (EPA, 2001). Based on the carcinogenicity of ionizing radiation, cancer slope factors have been derived for cesium-137. The oral slope factor for cesium-137 is 4.33×10^{-11} risk per pCi for soil ingestion, 1.19×10^{-11} risk per pCi for inhalation, and 5.32×10^{-10} risk per pCi for external effects.

Typical signs and symptoms of acute toxicity to cesium-137 are similar to those of exposure to ionizing radiation in general. These symptoms include vomiting, nausea, diarrhea, skin and ocular lesions, neurological signs, chromosomal abnormalities, compromised immune function, and death. Repeated exposures may cause reduced male fertility, abnormal neurological development following exposure during critical stages of fetal development, and genotoxic effects. Long-term cancer studies on exposed individuals have not been completed to date, and no studies were available that specifically address cesium-137 cancer effects on humans. Animal studies, however, indicate an increased risk of cancer from external or internal exposure to relatively high doses of cesium-137 radiation. No non-ionizing radiation effects of cesium were identified (ATSDR, 2004). In the absence of relevant data, provisional non-cancer risk assessment values based on cesium-induced effects that are not attributable to ionizing radiation have not been derived.

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CHLOROFORM

Chloroform is primarily used to produce the refrigerant chlorodifluoromethane, which is used in home air conditioners and large grocery store freezers. Other past uses of this chemical include its use as a solvent, a medium in fire extinguishers, an intermediate in dyes and pesticides, and as an anesthetic. However, it currently has limited medical uses in dental procedures and medications (ATSDR, 1997). Chloroform is also a common disinfection byproduct of chlorinated drinking water. The potential for human exposure is generally through exposure to drinking water via the oral, dermal, and inhalation routes (EPA, 2006, ATSDR, 1997).

The effects of chloroform on human health were observed when inhaled (used as an anesthetic) and ingested (EPA/635/R-01/001). In addition, several studies have been performed on animals that support the human data (EPA/635/R-01/001). The major effects observed when chloroform was inhaled as an anesthetic include liver, kidney, and central nervous system toxicity (ATSDR, 1997; EPA/635/R-01/001). The minor effects noted when chloroform was inhaled as an anesthetic (less than 22,500 ppm), include increase respiratory rates, cardiac hypotension and arrhythmia, and nausea and vomiting (ATSDR, 1997). Phoon et al. (1983) reported workers exposed to chloroform concentrations ranging from 14 to 400 ppm for 1 to 6 months developed toxic hepatitis and other effects including jaundice, nausea, and vomiting (ATSDR, 1997).

Similar major and minor health effects that occur from inhalation also occur after oral exposure to chloroform but at lower concentrations (less than 2,000 ppm) (EPA/635/R-01/001). Several studies (Piersol et al., 1933; Schroeder, 1965, Storms, 1973) reported that deep coma occurred immediately after intentional or accidental ingestion of 2,410 or 3,755 ppm (ATSDR, 1997). ATSDR (1997) reported that the overall human data are insufficient to conclude carcinogenicity from oral consumption; however, several animal studies found oral consumption to be carcinogenic. Chloroform has been shown to cause increased incidence of liver and kidney tumors in several species by several exposure routes (EPA/635/R-01/001).

EPA reports an oral RfD for chloroform of 0.01 mg/kg-day, based on a study of eight male and eight female dogs that were fed 15 or 30 mg chloroform/kg-day, 6 days/week for 7.5 years. The observed effects were fatty cysts forming on the liver. The RfD is based on a benchmark dose approach (coincidentally the same value as that obtained using the traditional NOAEL/LOAEL methodology) yielding a BMDL10 (benchmark dose limit associated with a 10 percent risk) of 1.2 mg/kg-day, an uncertainty factor of 100, and a modifying factor of 1. The EPA's overall confidence in the RfD is rated medium, based on the sufficiency of animal data; a higher rating is not given due to the limited human data (EPA, 2007).

The NCEA has derived a provisional inhalation reference concentration for chloroform of 0.05 mg/m^3 (0.014 mg/kg-day) (NCEA, 2002). The studies considered in the derivation of the inhalation reference concentration include studies in humans exposed to chloroform in the workplace, as well as inhalation studies of systemic and reproductive effects in animals (NCEA, 2002). Effects on liver and kidney have been observed following inhalation exposures in both humans and animals, and these effects are the most sensitive and characteristic indicators of toxicity following oral exposure. For these reasons, toxicity to liver and/or kidney was identified as the most appropriate effects for derivation of inhalation reference concentrations for chloroform. The critical studies selected for the derivation of the inhalation reference concentration were two subchronic studies in mice that measured histological and labeling index changes in liver and kidney following exposure for 6 hr/day, 5 to 7 days/week, for 90 days. The reference concentration was calculated from the NOAEL (adjusted to the human equivalent concentration) of 4.5 mg/m^3. An uncertainty factor of 100 was assigned, of which a factor of 10 was employed to account for protection of sensitive human subpopulations, a factor of 3 for potential interspecies variability, and a factor of 3 to account for uncertainties in the database. An added uncertainty factor was not used to account for use of a subchronic study since the available data indicate that effects following inhalation exposure are not strongly duration-dependent (NCEA, 2002).

According to the IRIS database (EPA, 2007), chloroform is classified as a probable human carcinogen (B2) based on increased incidence of tumors in rats, mice, and dogs from ingesting chloroform in food and water. However, as reported in the recent toxicological review of chloroform (EPA/635/R-01/001), under the EPA's guidelines for carcinogen risk assessment (EPA/630/P-03/001F), chloroform is likely to be carcinogenic to humans by all routes of exposure under high-dose conditions that lead to cytotoxicity and cell regeneration; and chloroform is not likely to be carcinogenic to humans by any routes of exposure at a dose level that does not cause cytotoxicity and cell regeneration. This weight-of-evidence conclusion indicates that noncarcinogenic effects from exposure to chloroform are the primary concern for human health, while carcinogenicity is secondary. This conclusion is supported by the finding that chloroform is not a strong mutagen and is not likely to cause cancer through a genotoxic mode of action (EPA/635/R-01/001). Thus, an oral slope factor has not been derived for chloroform and exposures that occur at or below the RfD will not result in cancer incidence at levels in excess of target health goals.

The IRIS database (EPA, 2007) reports an inhalation unit risk for chloroform of 2.3×10^{-5} $(\mu g/m^3)^{-1}$, which is equivalent to an inhalation slope factor of $0.081 (mg/kg\text{-}day)^{-1}$. This inhalation slope factor is based on increased incidence of hepatocellular carcinomas in female mice dosed with chloroform by oral gavage. However, EPA cautions the use of this slope factor in the evaluation of the carcinogenicity of chloroform through the inhalation pathway, because this value was derived in 1987 and does not incorporate newer data or the EPA's guidelines for carcinogen risk assessment (EPA/630/P-03/001F). The EPA is currently working to revise the assessment for inhalation exposure.

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CHROMIUM (TOTAL, HEXAVALENT)

Chromium is a naturally occurring element found in rocks, soil, plants, animals, and in volcanic dust and gases. The most common environmental forms are chromium (0), chromium (III) (trivalent chromium), and chromium (VI) (hexavalent chromium). Chromium (0), the metal chromium, is a gray solid and has a high melting point. This form is primarily used to make steel and other alloys. Trivalent chromium is used to line high-temperature industrial furnaces. Chromium-containing compounds are used in many industrial processes, such as stainless steel welding, chrome plating, and leather tanning (ATSDR, 2002).

Trivalent chromium is considered an essential nutrient that helps to maintain normal metabolism of glucose, cholesterol, and fat in humans. The minimum human daily requirement of chromium for optimal health is not known, but a daily ingestion of 50 to 200 μg/day (0.0007 to 0.003 mg/kg bw/day) has been estimated to be safe and adequate. The long-term effects of eating diets low in chromium are difficult to evaluate (ATSDR, 2002).

The three major forms differ in their effects on health. Hexavalent chromium is irritating, and short-term, high-level exposure can result in adverse effects at the site of contact, such as ulcers of the skin, irritation of the nasal mucosa and perforation of the nasal septum, and irritation of the gastrointestinal tract. Hexavalent chromium may also cause adverse effects in the kidney and liver. Trivalent chromium does not result in these effects and is the form that is an essential food nutrient when ingested in small amounts, although very large doses may be harmful. For example, ingesting large amounts can cause stomach upset and ulcers, convulsions, and kidney and liver damage. Very limited data suggest that trivalent chromium may have respiratory effects on humans. No data on chronic or subchronic effects of inhaled trivalent chromium in animals can be found. Adequate reproductive and developmental toxicity data do not exist. Information on chromium (0) health effects is limited. Animal studies have found that inhalation exposure had increased frequencies of chromosomal aberrations and sister chromatid exchanges in peripheral lymphocytes (ATSDR, 2002).

The oral RfD for trivalent chromium is 1.5 mg/kg-day based on a chronic rat feeding study and a NOAEL of 1,468 mg/kg-day. The uncertainty factor of 100 represents two 10-fold decreases in mg/kg bw-day dose that account for both the expected interhuman and interspecies variability to the toxicity of the chemical in lieu of specific data. An additional 10-fold modifying factor is applied to reflect database deficiencies. The overall confidence in this RfD assessment was rated low because of the lack of explicit detail on study protocol and results, the lack of high-dose supporting data, and the lack of an observed effect level. Thus, the RfD as given should be considered conservative (EPA, 2007).

Data are considered to be inadequate for development of an inhalation RfD for trivalent chromium due to the lack of a relevant toxicity study addressing respiratory effects of trivalent chromium (EPA, 2007). Data from animal studies have identified the respiratory tract as the primary target of chromium toxicity following inhalation of hexavalent chromium, and these data have been used for development of an RfC for hexavalent chromium particulates. However, these data do not demonstrate that the effects observed following inhalation of hexavalent chromium particulates are relevant to inhalation of trivalent chromium, and these data are considered to be inappropriate for development of an RfC for trivalent chromium (EPA, 2007).

The oral RfD for hexavalent chromium is 0.003 mg/kg-day based on a 1-year rat drinking water study and a NOAEL of 2.5 mg/kg-day. The uncertainty factor is 300. A factor of 10 each accounts for inter- and intra-species variability. An additional uncertainty factor of 3 was applied to compensate for the less-than-lifetime exposure duration of the principal study. A modifying factor of 3 was also applied to account for concerns raised by other studies. The overall confidence in this RfD assessment was rated low because of the lack of explicit detail on study protocol and results, the lack of high-dose supporting data, and the lack of an observed effect level. Thus, the RfD as given should be considered conservative (EPA, 2006).

The oral toxicity factor is adjusted to characterize risk from the dermal exposure pathway. This adjustment is made to estimate the absorbed dose from the toxicity indices that are based on administered dose. The percent GI absorption for chromium (VI) is 2.5 percent of the oral reference dose as recommended in the supplemental guidance for dermal risk assessment, resulting in a dermal RfD of 0.000075 mg/kg/day (EPA, 2004).

As described in EPA (2007) two inhalation RfCs have been derived for chromium (VI), one based on nasal mucosal atrophy following occupational exposures to chromic acid mists and dissolved hexavalent chromium aerosols, and a second based on lower respiratory effects following inhalation of chromium (VI) particulates in rats. For inhalation exposures to chromium VI in mists and aerosols, the RfC of 8×10^{-6} mg/m^3 is based on a human subchronic occupational study for upper respiratory effects caused by chromic acid mists and dissolved hexavalent chromium aerosols. The study LOAEL based on a TWA exposure to chromic acid was adjusted to account for continuous exposure and uncertainty factors of 3, 3, and 10 were applied to extrapolate from a subchronic to a chronic exposure, to account for extrapolation from a LOAEL to a NOAEL, and to account for interhuman variation, respectively. The total uncertainty factor applied to the LOAEL is 90.

EPA (2007) has also derived an inhalation RfC for chromium (VI) of 1×10^{-4} mg/m^3 to evaluate exposures to chromium VI in particulates and dusts. This value is based on a subchronic rat study that showed increased incidences of adverse effects on lung function. The inhalation RfC was calculated using the benchmark dose approach. An uncertainty factor of 300 was applied to the benchmark dose to account for pharmacodynamic differences, less-than-lifetime exposure, and variation in the human population.

Hexavalent chromium was not selected as a COPC in soil and was not evaluated for noncarcinogenic effects in soil or fugitive dust. During regular domestic water use, inhalation of non-volatiles is insignificant. Therefore, for the industrial worker and residential farmer scenario evaluated in this assessment, inhalation exposures to chromium (VI) are incomplete and were not evaluated. Therefore, neither of the inhalation RfCs for chromium (VI) was used in this risk assessment. However, for the sweatlodge scenario evaluated for Native American populations in Appendix G it was assumed that even nonvolatile contaminants could be suspended in the steam created within the sweatlodge. Therefore, hexavalent chromium was evaluated for in the Native American sweatlodge scenario, through the inhalation of hexavalent chromium in the steam within the sweatlodge (see Section J5.0), and the inhalation RfC of 8×10^{-6} mg/m^3 for chromium (VI) in mists and aerosols was used in Appendix G to evaluate inhalation exposures to chromium (VI) in sweatlodge vapors.

Of the three forms of chromium of toxicological importance, chromium (VI) is the most toxic. Chromium (VI) is classified by the EPA as a Group A, human carcinogen by inhalation, based on evidence that indicates sufficient cancer data in both animals and humans. Several epidemiological studies found an association between chromium exposure and lung cancer. The inhalation cancer SF for total chromium (one-sixth ratio of chromium VI:III) is 42 (mg/kg-day)-1 and is based on benign and malignant stomach tumor data in female mice (EPA, 2007). The inhalation SF for chromium (VI) was derived by multiplying the total chromium value by 7, yielding a inhalation slope factor of 209 $(mg/kg\text{-}day)^{-1}$.

Hexavalent chromium is a carcinogen by inhalation, but not by ingestion. As discussed above, for the industrial worker and residential farmer scenario evaluated in this assessment, inhalation exposures to chromium VI are incomplete and hexavalent chromium was not evaluated for carcinogenic effects. However, hexavalent chromium was evaluated for in the Native American sweatlodge scenario, through the inhalation of hexavalent chromium in the steam within the sweatlodge (see Section J5.0), and the inhalation slope factor of 209 $(mg/kg\text{-}day)^{-1}$for chromium (VI) was used in Appendix G to evaluate cancer risks from inhalation exposures to chromium (VI) in sweatlodge vapors.

References

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EUROPIUM-152

Europium is a silvery-white metal found in ores including bastnasite, monazite, and xenotime. Present in the earth's crust at about 1.8 mg/kg, europium occurs as two stable isotopes and 14 major radioactive isotopes. One of these radioactive isotopes is europium-152, which has a half-life of 13 years (ANL, 2007). This isotope emits beta particles and gamma rays as it decays.

The primary concern for exposure to europium-152 is the risk of exposure to ionizing radiation from beta particles and gamma rays. Ionizing radiation has been shown to be a human carcinogen, and EPA classifies all radionuclides as Group A carcinogens (EPA, 2001). Based on the carcinogenicity of ionizing radiation, cancer slope factors have been derived for europium-152. The oral slope factor for europium-152 is 1.62×10^{-11} risk per pCi for soil ingestion, 9.10×10^{-11} risk per pCi for inhalation, and 5.30×10^{-6} risk per pCi for external effects.

Once absorbed into the bloodstream, europium preferentially deposits in the liver, on the bone surface, and in the kidneys. External and internal exposures can increase the likelihood of liver and bone cancer. No non-ionizing radiation effects of europium-152 were identified. In the absence of relevant data, provisional non-cancer risk assessment values based on europium-induced effects that are not attributable to ionizing radiation have not been derived.

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IODINE-129

Iodine is a naturally occurring element primarily found as iodine-127, its most stable form. Iodine-129 is one of two radioactive isotopes that form naturally in the upper atmosphere (EPA, 2002). Iodine-129 and iodine-131 are emitted as beta and gamma radiation during iodine's decay process. Iodine-129 can be found in wastes from nuclear power facilities and defense-related government facilities (EPA, 2002, ANL, 2005). Both iodine nuclide forms have also been produced during nuclear weapons testing. However, the amount of anthropogenic iodine-129 is still less than naturally occurring levels. Of the two types, iodine-129 is the form with a long enough half-life to warrant long-term concern. The radiation and half-life information for iodine-129 and iodine-131 are presented in the table below. Iodine-129 has a half-life of 16 million years compared to approximately 8 days for iodine-131 (ANL, 2005).

Isotope	Half-Life	Specific Activity (Ci/g)	Decay Mode	Radiation Energy (MeV)		
				Alpha (α)	Beta (β)	Gamma (γ)
Iodine-129	16 million years	0.00018	β	-	0.064	0.025
Iodine-131	8.0 days	130,000	β	-	0.19	0.38

Note: Values from (ANL, 2005).

Iodine is a basic component of the human diet and is taken into the human body through all exposure pathways. Historically, a significant pathway for iodine-129 and iodine-131 ingestion has been the consumption of fruits and vegetables or milk from an iodine-contaminated area. Incidents such as Chernobyl can expose populations in the fallout area to high concentrations of both types of iodine, as well as long-term exposure to iodine-129 through all pathways. Following ingestion and inhalation, iodine is readily absorbed by the bloodstream from both the gastrointestinal tract and lungs. Approximately 30 percent of iodine in the human body ends up in the thyroid gland where it is used in hormone production (ANL, 2005). The primary radiological concern related to iodine-129 is the risk associated with exposure to beta radiation, which varies based on the dose of iodine isotopes (EPA, 2002). As a result, the main health concerns from iodine-129 and iodine-131 radiation are the development of thyroid tumors. In addition, the uptake of radioactive iodine by the thyroid gland is inversely related to the amount of stable iodine available (EPA, 2002); thus, exposures to accidental releases of iodine isotopes are often treated by the ingestion of large doses of stable iodine. Stable iodine has its own health effects related to large doses that must also be considered in this treatment.

Iodine-129 is a Group A radionuclide, which are classified by the EPA as known human carcinogens. The lifetime cancer mortality risk coefficients for iodine-129 are presented in the previous table. Epidemiological studies for iodine-129 have shown children to be the group most susceptible to thyroid cancer. Cancer treatment from radioactive iodine exposure must be evaluated on a case-by-case basis. Treatment concerns center around the use of radiation to treat tumors caused by radioactive isotopes. Treatments are typically only initiated when the benefits outweigh the risks.

Based on the carcinogenicity of ionizing radiation, cancer slope factors have been derived for iodine-129. The slope factors for iodine-129 is 3.2×10^{-10} risk per pCi for food ingestion, 1.5×10^{-10} risk per pCi for water ingestion, 6.1×10^{-11} risk per pCi for inhalation, and 6.1×10^{-9} risk per pCi for external effects (EPA, 2001).

References

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MANGANESE

Manganese is an essential element in human nutrition, serving as a co-factor in several enzymatic reactions. When ingested, manganese is considered to be among the least toxic of the trace elements. The adverse health effects from manganese are principally associated with inhalation exposure in the workplace. Acute inhalation exposure can produce irritation of the respiratory tract. Chronic inhalation exposure can produce a central nervous system disorder resembling Parkinsonism, known as manganism (ATSDR, 2000).

Toxic Effects

Daily intake of manganese ranges from 2 to 9 mg/day. Manganese is poorly absorbed following oral exposure, and reports of human intoxication following ingestion exposures are not common. However, some studies suggest that neurological effects may be associated with the consumption of drinking water with elevated levels of manganese (ATSDR, 2000).

Several studies have shown that inhalation of manganese in occupational settings is associated with neurological effects. The principal signs of manganism include tremors, weakness in the legs, staggering gait, behavioral disorders, slurred speech, and a fixed facial expression. There is no evidence indicating that inhalation exposure to manganese is carcinogenic in humans; however, there is some evidence of male reproductive effects (ATSDR, 2000).

Development of the oral RfD for manganese recognizes that disease states in humans have been associated with both deficiencies and excessive intakes of manganese. The oral RfD for manganese is set at 10 mg/day (0.14 mg/kg-day) and is based on the upper end of the normal dietary intake rate. This value is considered a NOAEL for dietary intake and has not been adjusted by an uncertainty factor. The EPA emphasizes that individual requirements for, as well as adverse reactions to, manganese may be highly variable. The RfD is estimated to be an intake for the general population that is not associated with adverse health effects; this is not meant to imply that intakes above the RfD are necessarily associated with toxicity (EPA, 2007).

The oral RfD for manganese was evaluated further in other media (drinking water or soil) based on an epidemiological study of manganese in drinking water (EPA, 2007). Whereas the results from this study do not allow a quantitative evaluation of dose response, they raise concerns about possible adverse neurological effects at doses not far from the range of essentially. For assessing exposure to manganese from drinking water or soil, EPA (1999) recommends adjustment by an uncertainty factor of 3, yielding an oral RfD of 0.024 mg/kg-day. Four reasons are provided for the use of an uncertainty factor to adjust the oral RfD for soil and water exposure: (1) in fasted individuals, there may be increased uptake of manganese from water; (2) the study raises some concern regarding possible adverse health effects associated with a lifetime consumption of drinking water with manganese concentration of about 2 mg/L; (3) because infant formula typically has a much higher concentration of manganese than that of human milk, manganese in the water could represent an additional source of intake for infants; and (4) neonates may absorb more manganese from the gastrointestinal tract and may be less able to excrete absorbed manganese, and absorbed manganese may more easily cross their blood-brain barrier.

For this risk assessment, the non-food oral RfD of 0.07 mg/kg-day was used to evaluate the ingestion of manganese in soil (EPA, 1999). For dermal exposures to the chemical in soil, the oral RfD was adjusted by a factor of 4 percent as recommended by EPA (EPA/540/R/99/005, Exhibit 4-1). This adjustment results in a dermal RfD of 0.0028 mg/kg-day.

The inhalation RfD of 0.000014 mg/kg-day for manganese (EPA, 2007) suggests that inhaled manganese may be much more toxic than ingested manganese. Differences in absorption between the two routes cannot alone account for this large difference. The EPA reports that after absorption into blood via the respiratory tract, manganese is transported through the blood stream directly to the brain, bypassing the initial clearance effects of the liver. EPA reports that this pathway from the respiratory tract to the brain is the primary reason for the differential toxicity between inhaled and ingested manganese. In addition, recent studies in animals have shown that manganese has a unique ability among metals to be taken up in the brain via olfactory pathways (Tjalve and Henriksson, 1997). This process involves direct diffusion of manganese from the nasal cavity to the central nervous system without entering blood, therefore bypassing both the initial clearance effects of the liver and the blood-brain barrier (Tjalve and Henriksson, 1997). This direct pathway to the central nervous system might account in part for the higher toxicity of inhaled manganese.

Carcinogenicity

Although ingestion exposure studies suggest that manganese may be weakly carcinogenic in laboratory animals, these data are inadequate to support a classification as carcinogenic by the EPA. The EPA has categorized manganese as Group D, not classifiable with regard to human carcinogenicity (EPA, 2007).

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METHYLENE CHLORIDE

Methylene chloride, also known as dichloromethane, is a colorless liquid that has a mild sweet odor, evaporates easily, and does not easily burn. The odor threshold for methylene chloride in air is approximately 200 ppm. Methylene chloride is primarily used as an industrial solvent and paint stripper. It can be found in certain aerosol and pesticide products and is used in the manufacture of photographic film. The chemical may be found in some spray paints, automotive cleaners, and other household products. Methylene chloride does not appear to occur naturally in the environment. Most of the methylene chloride released to the environment results from its use as an end product by various industries and the use of aerosol products and paint removers in the home (ATSDR, 2000).

In humans, acute inhalation exposure to methylene chloride at concentrations of 300 ppm or greater is known to impair hearing and vision (Winneke, 1974). Exposure to 800 ppm or greater methylene chloride can slow reaction times, impair motor skills, and cause dizziness, nausea, and drunkenness (Stewart et al., 1972; Winneke, 1974). Dermal exposure to methylene chloride causes intense burning and mild redness of the skin. Methylene chloride has not been shown to cause cancer in humans with chronic inhalation exposures to vapors in the workplace. In animals, inhalation of methylene chloride has been shown to adversely affect the liver and kidneys of rats (Stewart et al., 1974) and the corneas of rabbits (Ballantyne et al., 1976).

The EPA has established an oral RfD for methylene chloride of 0.06 mg/kg-day, based on a study reporting histological alterations of the liver in rats exposed to 50, 125, and 250 mg/kg-day methylene chloride for 2 years (NCA, 1982). The oral RfD was calculated by applying an uncertainty factor of 100 (to account for interspecies extrapolation and intraspecies extrapolation to protect sensitive human populations) and a modifying factor of 1 to the reported NOAEL of 5.85 mg/kg-day. Although the study used to derive the RfD was given a high confidence rating, the overall confidence in the RfD is rated medium because only a few studies support the NOAEL (EPA, 2007).

The EPA has established an inhalation RfC for methylene chloride of 3.0 mg/m^3, based on a 2-year chronic exposure study reporting hepatic toxicity in rats exposed to methylene chloride (Nitschke et al., 1988). The inhalation RfC was calculated by applying an uncertainty factor of 100 (to account for interspecies extrapolation and intraspecies extrapolation to protect sensitive individuals) to the reported NOAEL of 694.8 mg/m^3.

The EPA has classified methylene chloride as a probable human carcinogen (Group B2) based on increased incidence of tumors in several organs of rats and mice, including the liver (NCA, 1982; 1983), lung (NTP, 1986), mammary and salivary glands (Burek et al., 1984; NTP, 1986), and blood (NTP, 1986). This classification is supported by some positive genotoxicity data, although results in mammalian systems are generally negative. The oral slope factor for methylene chloride (calculated using data from the NCA and NTP studies) is 0.0075 $(mg/kg\text{-}day)^{-1}$. The inhalation slope factor for methylene chloride (calculated using data from the NTP study) is 4.7E-07 $(\mu g/cm^3)^{-1}$.

References

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NEPTUNIUM-237

Roughly twice as dense as lead, neptunium is an artificially produced metal created through neutron capture reactions by uranium. All 17 known isotopes are radioactive. Neptunium-237 has a half-life of 2.1 million years and releases alpha, beta, and gamma radiation as it decays (ANL, 2007).

The primary concern for exposure to neptunium-237 is the risk of exposure to ionizing alpha, beta, and gamma radiation. Based on the carcinogenicity of ionizing radiation, cancer slope factors have been derived for neptunium-237. The oral slope factor for neptunium-237 is 1.46×10^{-10} risk per pCi for soil ingestion, 1.77×10^{-8} risk per pCi for inhalation, and 5.36×10^{-8} risk per pCi for external effects (EPA, 2001).

Neptunium entering the bloodstream tends to be deposited in the skeleton but is also preferentially deposited in the liver and other soft tissues. Cancer may result from ionizing radiation emitted by neptunium deposits on the bone surfaces, liver, and soft tissues. The external risk posed by neptunium is predominantly due to its gamma radiation emissions and the radiation released by its short-lived decay product, protactinium-233. No non-ionizing radiation effects of neptunium were identified. In the absence of relevant data, provisional non-cancer risk assessment values based on neptunium-induced effects that are not attributable to ionizing radiation have not been derived.

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NICKEL-63

Usually found in combination with other elements, nickel is a naturally occurring metal in the earth's crust. Nickel is found in soil and emitted from volcanoes, comprises 6 percent of the earth's core, and is the 24th most abundant element. Nickel occurs in five stable isotopes: nickel-58, nickel-60, nickel-61, nickel-62, and nickel-64. Nickel-63 is one of six major radioactive isotopes. Nickel-63 has a half-life of 96 years and decays by emitting a beta particle (ANL, 2007).

The primary concern for exposure to nickel-63 is the risk of exposure to ionizing radiation from beta particles. Ionizing radiation has been shown to be a human carcinogen, and EPA classifies all radionuclides as Group A carcinogens (EPA, 2001). Based on the carcinogenicity of ionizing radiation, cancer slope factors have been derived for nickel-63. The oral slope factor for nickel-63 is 1.79×10^{-12} risk per pCi for soil ingestion, 1.64×10^{-12} risk per pCi for inhalation, and 0 risk per pCi for external effects.

Of nickel that is absorbed into the bloodstream, about 2 percent remains in the kidneys and 30 percent is distributed to all remaining tissues (ANL, 2007); the remainder is excreted. Nickel can also be absorbed by and retained in the skin. Nickel also may produce nonradiological chemical effects in the 10 percent to 15 percent of the population that has nickel sensitivity (ANL, 2007). These chemical effects may include skin allergies and asthma attacks. Acute toxicity from nickel dust exposure may adversely affect the gastrointestinal system, blood, and kidneys. Chronic exposure to airborne nickel dust may cause bronchitis, reduced lung function, and cancer of the lung and nasal sinus.

References

ANL, 2007, *Radiological and Chemical Fact Sheets to Support Health Risk Analysis for Contaminated Areas*, dated March 2007, Argonne National Laboratory, Environmental Science Division, Argonne, Illinois.

EPA, 2001, *Update of Radionuclide Toxicity of the Health Effects Assessment Summary Tables (HEAST)*, dated April 16, 2001, U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C.

NITRATE

Nitrate (NO_3^-) and nitrite (NO_2^-) are part of the naturally occurring nitrogen cycle. Microbial activity in soil or water breaks down wastes that contain organic nitrogen into ammonia, which are later oxidized to nitrate and nitrite. Nitrogen-containing compounds are generally soluble in soil and quickly enter the groundwater. Nitrite is then readily oxidized to its more toxic form of nitrate. Nitrate is naturally occurring in groundwater and surface waters; however, these levels can be raised significantly by contamination with nitrogen-containing fertilizers (including animal or human natural organic wastes or anhydrous ammonia). The use of shallow groundwater wells in the U.S. means that many humans have the potential to consume drinking water contaminated by nitrates. Nitrates are also naturally occurring in various foods including meats, vegetables, and prepared foods (e.g., sausages).

A condition known as "blue baby syndrome." which leads to bluish lips and sometimes death, affects infants less than 3 months old (ATSDR, 2001). This condition is often caused by formula that has been diluted with water from a water source with high nitrate levels. Since infants often have a higher gut pH, it enhances the conversion of ingested nitrate to the more toxic nitrite. It has been shown that the incidence of gastroenteritis with vomiting and diarrhea can exacerbate nitrite formation.

The toxicity associated with nitrate is the result of its conversion to nitrite. Nitrite in the bloodstream oxidizes the iron in hemoglobin from Fe(+2) to Fe(+3), resulting in methemoglobin (ATSDR, 2001). Methoglobin leads to reduced oxygen transport from the lungs to tissues because it does not bind with oxygen. It is not uncommon for individuals to have low levels of methemoglobin from 0.5 percent to 2.0 percent because blood has a large capacity to carry oxygen (ATSDR, 2001). As a result, even levels under 10 percent are not associated with any significant clinical signs (ATSDR, 2001). Concentrations that exceed 10 percent can lead to cyanosis (a bluish color to skin and lips), and concentrations that exceed 25 percent can lead to weakness, rapid pulse, and tachypnea (ATSDR, 2001). Methoglobin levels that exceed 50 percent to 60 percent may lead to death.

The NOAEL oral RfD of 1.6 mg/kg/day for nitrate was derived based on two studies in the 1950s, which determined that infantile methemoglobinemia only occurs at concentrations in water greater than 10 mg nitrate-nitrogen/L (EPA, 2007). The typical daily intake of an adult in the U.S. is about 75 mg/day (about 0.2 to 0.3 mg nitrate- nitrogen/kg/day) (ATSDR, 2001). The assigned uncertainty factor for nitrate is 1 because of the NOAEL value for humans is based on the most sensitive case (EPA, 2007).

A RfC for chronic inhalation exposure is not available at this time

Carcinogenicity

The carcinogenicity of nitrate is not available at this time.

References

ATSDR, 2001, *Case Studies in Environmental Medicine Nitrate/Nitrite Toxicity*, dated January 2001, U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Washington, D.C.

EPA, 2007, *Integrated Risk Information System (IRIS) Online Database*, accessed in April 2007, http://www.epa.gov/iris/index.html, U.S. Environmental Protection Agency, Washington, D.C.

PLUTONIUM-238, -239, AND -240

Plutonium is a radioactive metal that is produced when uranium absorbs an atomic particle. Small amounts of plutonium occur naturally, but large amounts have been produced in nuclear reactors. All plutonium isotopes are radioactive, and three common plutonium isotopes are plutonium-238, -239, and -240. Alpha, beta, and gamma radiation are released as plutonium decays (ATSDR, 1990, ANL, 2007). The half-lives of plutonium-238, plutonium-239, and plutonium-240 are 86 years, 24,000 years, and 6,500 years, respectively.

The primary concern for exposure to plutonium is the risk of exposure to ionizing alpha, beta, and gamma radiation. Ionizing radiation has been shown to be a human carcinogen, and the EPA classifies all radionuclides as Group A carcinogens (EPA, 2001). Based on the carcinogenicity of ionizing radiation, cancer slope factors have been derived for plutonium isotopes -238, -239, and -240. The oral slope factors for plutonium-238, plutonium-239, and plutonium-240 are 2.72 x 10-^{10}, 2.76×10^{-10}, and 2.77×10^{-10} risk per pCi. For inhalation, the slope factors for plutonium-238, plutonium-239, and plutonium-240 are 3.36×10^{-8}, 3.33×10^{-8}, and 3.33×10^{-8} risk per pCi, respectively. For external effects, slope factors for these isotopes are 7.22×10^{-11}, 2.00×10^{-10}, and 6.98×10^{-11} risk per pCi, respectively.

Although plutonium has not definitively been shown to cause adverse health effects in humans, animal studies have reported increased lung, liver, and bone cancers, as well as adverse effects on the blood and immune system from plutonium exposure. Animal studies have also found lung diseases from short-term exposure to high concentrations of plutonium. No non-ionizing radiation effects of plutonium were identified (ATSDR, 1990). In the absence of relevant data, provisional non-cancer risk assessment values based on plutonium-induced effects that are not attributable to ionizing radiation have not been derived.

References

ATSDR, 1990, *Toxicological Profile for Plutonium*, U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Washington, D.C.

ANL, 2007, *Radiological and Chemical Fact Sheets to Support Health Risk Analysis for Contaminated Areas*, dated March 2007, Argonne National Laboratory, Environmental Science Division, Argonne, Illinois.

EPA, 2001, *Update of Radionuclide Toxicity of the Health Effects Assessment Summary Tables (HEAST)*, dated April 16, 2001, U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C.

PROTACTINIUM-231

One of the rarest naturally occurring elements, protactinium is present in uranium ores at a concentration of 1 part protactinium to 3 million parts uranium (ANL, 2007). All three of its naturally occurring isotopes (protactinium-231, protactinium-234, and protactinium-234m) are radioactive. Of the three, protactinium-231 is the most common and with a half-life of 33,000 years, it has the longest half-life. Protactinium-231 is a decay product of uranium-235. Protactinium-231 emits alpha, beta, and gamma radiation as it decays to actinium-227. Much of the human health hazard associated with protactinium-231 is attributable to actinium-227. Actinium-227 has a half-life of 22 years and decays by emitting an alpha or beta particle.

The primary concern for exposure to protactinium is the risk of exposure to ionizing alpha, beta, and gamma radiation. Based on the carcinogenicity of ionizing radiation, cancer slope factors have been derived for protactinium-231. The oral slope factor for protactinium-231 is 3.74×10^{-10} risk per pCi for soil ingestion, 4.55×10^{-8} risk per pCi for inhalation, and 1.39×10^{-7} risk per pCi for external effects (EPA, 2001).

Protactinium causes the most concern for human health through internal exposures when it is ingested or inhaled. Once in the bloodstream, protactinium preferentially deposits in the skeleton, with lesser amounts depositing in the liver and kidneys (ANL, 2007). There is a small external risk associated with the gamma rays emitted by protactinium-231. Cancer may be induced from ionizing radiation emitted by protactinium deposited in the skeleton, liver, and kidneys. No non-ionizing radiation effects of protactinium-231 were identified. In the absence of relevant data, provisional non-cancer risk assessment values based on protactinium-induced effects that are not attributable to ionizing radiation have not been derived.

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ANL, 2007, *Radiological and Chemical Fact Sheets to Support Health Risk Analysis for Contaminated Areas*, dated March 2007, Argonne National Laboratory, Environmental Science Division, Argonne, Illinois.

EPA, 2001, *Update of Radionuclide Toxicity of the Health Effects Assessment Summary Tables (HEAST)*, dated April 16, 2001, U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C.

RADIUM

Radium is an alkaline earth metal that has 25 isotopes with atomic weights ranging from 206 to 230; all of the radium isotopes are radioactive. The four naturally occurring radium isotopes are radium-223, radium-224, radium-226, and radium-228. Radium-223 and radium-224 are alpha emitters with relatively short half-lives of 11.4 and 3.6 days, respectively (ATSDR, 1990). Radium-226 is also an alpha emitter but has a very long half-life (1,600 years). Radium-228 is a beta emitter with a half-life of 5.7 years.

The primary concern for exposure to radium is the risk of exposure to ionizing radiation from alpha or beta particles. Ionizing radiation has been shown to be a human carcinogen, and the EPA classifies all radionuclides as Group A carcinogens (EPA, 2001). Based on the carcinogenicity of ionizing radiation, cancer slope factors have been derived for radium isotopes. The oral slope factors for radium-223, radium-224, radium-226, and radium-228 are 2.34×10^{-10}, 1.49×10^{-10}, $2.95 \times 10\text{-}^{10}$, and 2.46×10^{-10} risk per pCi, respectively, and the inhalation slope factors are 3.60×10^{-9}, 2.25×10^{-9}, 2.72×10^{-9}, and 9.61×10^{-10} risk per pCi, respectively (EPA, 2001).

A number of adverse effects (including death, anemia, leukemia, and osteosarcomas) were observed in humans and animals following oral, inhalation, and/or dermal exposure to radium isotopes. These effects have been attributed to the ionizing radiation. No studies examining non-ionizing radiation effects of radium were identified (ATSDR, 1990; In the absence of relevant data, provisional non-cancer and cancer risk assessment values based on radium-induced effects that are not attributable to ionizing radiation have not been derived.

References

ATSDR, 1990, *Toxicological Profile for Radium*, TP-90-22, U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Washington, D.C.

EPA, 1988, *Health Effects Assessment for Radium (226Ra, 228Ra, 224Ra)*, U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office, Cincinnati, Ohio.

EPA, 2001, *Update of Radionuclide Toxicity of the Health Effects Assessment Summary Tables (HEAST)*, dated April 16, 2001, U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C.

STRONTIUM-90

Strontium is a naturally occurring common element that is usually found in nature in the form of strontium-84, strontium-86, strontium-87, and strontium-88. The most common radioactive isotope, strontium-90, does not occur naturally and is found in spent fuel rods in nuclear reactors. Strontium-90 gives off beta particles and decays into yttrium-90, which is also radioactive (ATSDR, 2004). Strontium-90 has a half-life of 29 years.

The primary concern for exposure to strontium is the risk of exposure to ionizing radiation from beta particles. Based on the carcinogenicity of ionizing radiation, cancer slope factors have been derived for strontium-90. The oral slope factor for strontium-90 is 9.18×10^{-11} risk per pCi for soil ingestion, 1.05×10^{-10} risk per pCi for inhalation, and 4.82×10^{-10} risk per pCi for external effects (EPA, 2001).

A number of adverse effects (including leukemia and cancers of the bone, nose, lung, and skin) were observed in humans and animals following oral, inhalation, and/or dermal exposure to radioactive strontium isotopes. Oral exposure to absorbed radioactive strontium led to necrotic lesions, cancers of the bone and adjacent tissues, acute radiation syndrome, steosacroma, and immunosuppression. Inhalation of soluble particles tends to create effects similar to ingested doses. In animal studies, inhalation exposures of insoluble particles led to pneumonitis, necrosis of the pulmonary, vascular, and adjacent myocardial tissues, pulmonary fibrosis, and pulmonary and vascular cancers. Bone marrow effects are the most serious immediate consequences of exposure to high levels of radioactive strontium either by inhalation or oral route. If strontium-90 incorporates into the bone, irradiation of the bone marrow results in hypoplasia of the hemopoietic tissue and pancytopenia. At high doses, external doses of beta radiation can cause adverse effects such as erythema, ulceration, or tissue necrosis. All of these adverse effects have been attributed to the ionizing radiation. No studies examining non-ionizing radiation effects of strontium-90 were identified (ATSDR, 2004). In the absence of relevant data, provisional non-cancer and cancer risk assessment values based on strontium-induced effects that are not attributable to ionizing radiation have not been derived.

References

ATSDR, 2004, *Toxicological Profile for Strontium,* U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Washington, D.C.

EPA, 2001, *Update of Radionuclide Toxicity of the Health Effects Assessment Summary Tables (HEAST),* dated April 16, 2001, U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C.

TECHNETIUM-99

Essentially all of technetium found on earth is present as a result of human action. All isotopes of this silver-gray metal are radioactive and of its 10 major isotopes, only three are long-lived. The most important of these isotopes is technetium-99, with a half-life of 213,000 years. This isotope decays to the stable isotope ruthenium-99 by emitting a beta particle. With its long half-life, the radiation produced by this isotope is somewhat of less concern than other radioactive materials.

The primary concern for exposure to technetium is the risk of exposure to ionizing radiation from beta particles. Based on the carcinogenicity of ionizing radiation, cancer slope factors have been derived for technetium-99. The oral slope factor for technetium-99 is 7.66×10^{-12} risk per pCi for soil ingestion, 1.41×10^{-11} risk per pCi for inhalation, and 8.14×10^{-11} risk per pCi for external effects (EPA, 2001).

Technetium pertechnetate (TcO4) is well absorbed by the intestines and lungs following ingestion or inhalation. After reaching the bloodstream, technetium pertechnetate preferentially deposits in the thyroid, stomach wall, and the liver (ANL, 2007). Specific target organs for technetium deposits vary depending on the chemical form of technetium. With no associated gamma radiation, technetium poses little external harm. No non-ionizing radiation effects of technetium-99 were identified. In the absence of relevant data, provisional non-cancer risk assessment values based on technetium-induced effects that are not attributable to ionizing radiation have not been derived.

References

ANL, 2007, *Radiological and Chemical Fact Sheets to Support Health Risk Analysis for Contaminated Areas*, dated March 2007, Argonne National Laboratory, Environmental Science Division, Argonne, Illinois.

EPA, 2001, *Update of Radionuclide Toxicity of the Health Effects Assessment Summary Tables (HEAST)*, dated April 16, 2001, U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C.

TETRACHLOROETHYLENE

Tetrachloroethylene (PCE) is a synthetic chlorinated hydrocarbon used as an industrial solvent and degreaser. It is also extensively used in the dry cleaning and textile industries and as an intermediate in the manufacture of other chemicals (ATSDR, 1997). Chronic inhalation exposure of mice and rats to concentration of PCE resulted in liver cell carcinomas in male and female mice, an increased incidence of mononuclear cell leukemia in male and female rats, and an increase of renal tubular cell tumors in male rats (ATSDR, 1997).

The slope factors for PCE are not available on the IRIS database, although they are reported in the risk assessment issue paper for carcinogenicity information for tetrachloroethylene (NCEA in EPA, 1998) and in EPA Region 6's human health screening level tables (EPA, 2006). The oral slope factor as listed was 0.54 $(mg/kg\text{-}d)^{-1}$ and the inhalation SF was 0.021 $(mg/kg\text{-}d)^{-1}$ for PCE.

The chronic oral RfD of 1.0×10^{-2} mg/kg-day for PCE was derived based on a 6-week gavage study in mice that resulted in liver toxicity (EPA, 1998). The assigned uncertainty factor of 1,000 for PCE accounts for intraspecies variability and extrapolation of a subchronic effect level to its chronic equivalent. The RfD confidence level is considered medium (EPA, 1998). The inhalation RfD of 0.114 mg/kg-day used in the risk assessment was reported in the EPA Region 6 human health screening level tables (EPA, 2006).

References

ATSDR, 1997, *Toxicological Profile for Tetrachloroethylene*, dated September 1997, U.S, Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Washington, D.C.

EPA, 1998, *National Center for Environmental Assessment (NCEA) Risk Assessment Issue Papers on PCE and TCE*, dated November 1998, U.S. Environmental Protection Agency, Superfund Technical Support Center, Washington, D.C.

EPA, 2006, *EPA Region 6 Human Health Medium-Specific Screening Levels 2007 and Supplemental Information*, dated December 14, 2006, U.S. Environmental Protection Agency, Dallas, Texas.

THALLIUM

Thallium is one of the more toxic metals. At varying concentrations, thallium affects the neurological, hepatic, and renal systems. Temporary hair loss and decreased visual abilities have occurred in the occupational setting after ingestion of thallium. Chronic effects from ingestion in humans have been reported (as case studies) to produce gastrointestinal effects, liver, and kidney damage, although the kidney evidence is weak (ATSDR, 1992).

Toxic Effects

The oral RfD of 6.6×10^{-5} mg/kg-day for thallium and compounds is reported by EPA (2006). An IRIS record is available for thallium sulfate (EPA, 2007). This compound was used by EPA (2006) to derive RfDs for thallium compounds. The RfD reported in IRIS for thallium sulfate is 8×10^{-5} mg/kg-day and is based on NOAEL from a 90-day study in rats by EPA (1986). The IRIS record notes that no histopathological effects were observed, nor were there any differences between control and experimental groups in body weight, weight gain, food consumption, or absolute and relative organ weights. Dose-related increases were reported for alopecia (hair loss), lacrimation (tearing), and exophthalmos (bulging of eyes). Possible subtle changes in blood chemistry were also reported including increased enzyme levels of serum glutamic oxaloacetic transaminase (SGOT) and lactate dehydrogenase (LDH), increased sodium, and decreased glucose (EPA, 1986). Not all changes were significantly different from controls for both sexes. EPA (1986) also concluded that liver function was probably not affected because of lack of changes in serum glutamic pyruvic transaminase (SGPT) levels, and none of the blood chemistry changes observed significantly affected the health of the animals. In addition, differences in blood chemistry parameters were greatest between treated animals receiving thallium sulfate and non-treated controls. Differences between animals receiving thallium sulfate and vehicle controls receiving water were more subtle.

The uncertainty factor is relatively high (3,000) and likely incorporates factors of 10 to account for interspecies conversion, extrapolation from a subchronic study, variation in individual sensitivity, and an additional modifying factor of 1. The chronic RfD was withdrawn from the IRIS database and is currently under review by the EPA. ATSDR (1992) reports general lack of animal and human data by all routes of exposure for thallium.

Carcinogenicity

Thallium is listed as a Class D carcinogen (EPA, 2003). The basis for the classification is a lack of carcinogenicity data available for either humans or animals. The two human studies reviewed by the EPA were judged inadequate to determine carcinogenic effects because one study had no exposure quantification data, a small sample size, and an unknown length of observation period, and the other study's evaluation of exposure did not include a measure of carcinogenic response.

References

ATSDR, 1992, *Toxicological Profile for Thallium*, dated July 1992, U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Washington, D.C.

EPA, 2006, *U.S. EPA Region 6 Human Health Medium-Specific Screening Levels 2007 and Supplemental Information*, dated December 14, 2006, U.S. Environmental Protection Agency, Dallas, Texas.

EPA, 2007, *Integrated Risk Information System (IRIS) Online Database*, accessed in April 2007, http://www.epa.gov/iris/index.html, U.S. Environmental Protection Agency, Washington, D.C.

THORIUM

Thorium is a metallic element in the actinide series; the atomic weight of the 12 thorium isotopes range from 223 to 234; all of the isotopes are radioactive. The predominant thorium isotope found in the environment is thorium-232; this isotope makes up 99.99 percent of the naturally occurring thorium. The other two thorium isotopes found in the environment are thorium-228 and thorium-230. Thorium-232, -228, and -230 are alpha emitters with half-lives of 1.4×10^{10} years, 1.91 years, and 7.54×10^{4} years, respectively.

The primary concern for exposure to thorium is the risk of exposure to ionizing radiation from alpha particles. Ionizing radiation has been shown to be a human carcinogen, and the EPA classifies all radionuclides as Group A carcinogens (EPA, 2001). Based on the carcinogenicity of ionizing radiation, cancer slopes factors have been derived for thorium isotopes. The oral slope factors for thorium-228, thorium-230, and thorium-232 are 6.29×10^{-11}, 3.75×10^{-11}, and 3.28×10^{-11} risk per pCi, respectively and the inhalation slope factors are 9.45×10^{-8}, 1.72×10^{-8}, and $1.93\times \times 10^{-8}$ risk per pCi, respectively (EPA, 2001).

Most of the available data on the toxicity and carcinogenicity of thorium in humans are derived from individuals exposed to thorotrast (colloidal thorium-232 dioxide) administered intravenously as a radiological contrast medium. The most common adverse effects associated with thorotrast exposure are cirrhosis of the liver, hepatic tumors, and blood dyscrasias; these effects have been attributed to the alpha radiation (ATSDR, 1990). Respiratory effects and increased incidences of pancreatic, lung, and hematopoietic cancers have been reported in humans and animals following inhalation exposure to thorium (ATSDR, 1990); these effects have also been attributed to alpha radiation. No non-ionizing radiation effects of thorium were identified (ATSDR, 1990). In the absence of relevant data, provisional non-cancer and cancer risk assessment values were not derived for thorium-induced effects not attributable to ionizing radiation.

References

ATSDR, 1990, *Toxicological Profile for Thorium*, TP-90-25, U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry, Washington, D.C.

EPA, 2001, *Update of Radionuclide Toxicity of the Health Effects Assessment Summary Tables (HEAST)*, dated April 16, 2001, U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, Washington, D.C.

TRICHLOROETHYLENE

Trichloroethylene (TCE) has been in commercial production for more than 75 years in the U.S.. TCE has been extensively used for degreasing of fabricated metal parts, in dry cleaning, and as a solvent for oils, resins, waxes, paints, lacquers, printing inks, fabric dyes, disinfectants, and as an intermediate in the manufacture of other chemicals.

The EPA recently evaluated health risks from exposure to TCE in a document titled *Trichloroethylene Health Risk Assessment: Synthesis and Characterization* (EPA/600/P-01/002A). This document is an external review draft to which EPA is soliciting comments and its findings are subject to change; however, its findings are used in this report as the latest available information for TCE.

Previous investigations suggested that TCE's cancer classification be on a B2 to C continuum, indicating that there was some evidence for its carcinogenicity in animals and no evidence in humans. However, EPA's recent review of the literature recommended that TCE be considered "highly likely" to produce cancer in humans and has proposed that TCE be classified as a B1 carcinogen – a probable human carcinogen with sufficient evidence in animals and limited evidence in humans. The reasons for the increased certainty in the chemical's ability to cause cancer in humans are due to new epidemiological evidence and new information on the ways in which TCE could be inducing cancer (modes of action). The information on TCE carcinogenicity is complex and consistent responses are not seen across species. The metabolism of TCE is also complex and various metabolites are likely involved in the carcinogenic process. In addition, humans are exposed to TCE metabolites from other sources than just TCE, and some researchers consider that background exposures to these metabolites may affect a person's response to TCE. There is also some evidence that the human population could have subpopulations that are particularly sensitive to TCE because of (1) genetic predisposition, (2) environmental factors such as the consumption of alcohol, and (3) age (i.e., children may be more sensitive than adults).

Five types of cancer in humans are potentially linked with TCE exposure: liver, kidney, lymph-hematopoietic, cervical, and prostate. Given the complexity of the cancer data, several studies with liver, kidney, and lymphoma cancer data (for which there is supporting animal information) were used to derive a range of slope factors from 0.02 $(mg/kg\text{-}day)^{-1}$ to 0.4 $(mg/kg\text{-}day)^{-1}$. The EPA considers that these slope factors represent "a middle range of risk estimates where confidence is greatest." The lower end of this range, 0.02 $(mg/kg\text{-}day)^{-1}$ is based on the incidence of kidney cancer in German cardboard workers exposed to TCE in the workplace, while the higher end is based on the incidence of non-Hodgkin's lymphoma in females exposed to TCE in their drinking water.

The external review draft also evaluated the non-cancer effects associated with TCE exposures. An inhalation RfD of 0.011 mg/kg-day was derived from five studies (four in humans and one in rodents) based on effects in the central nervous system, liver, and endocrine system (EPA/600/P-01/002A). The EPA has selected an uncertainty factor of 1,000 for this RfD to account for subchronic to chronic extrapolation, interspecies variability and intraspecies variability.

The EPA recommends an oral RfD of 0.0003 mg/kg-day based on central nervous system, liver, and endocrine effects in a subchronic mouse study. The NCEA used EPA's maximum uncertainty factor of 3,000 to adjust the study NOAEL to an oral RfD, by NCEA considered the data sufficiently equivocal that even an uncertainty factor of 5,000 might be appropriate (EPA/600/P-01/002A).

The U.S. Department of Defense (DOD) has published a critique of EPA's proposed slope factor range for TCE (AFIERA, 2001). In particular, they note that the upper end of the proposed recommended range, 0.4 $(mg/kg\text{-}day)^{-1}$, is based on a residential drinking water study where the confidence interval around the calculated relative risk included one. The relative risk is defined as the cancer incidence rate in the exposed population relative to an unexposed population. If the relative risk is one, cancer incidence rates are equal for the exposed and unexposed populations and the study cannot conclude that there is an increased association between cancer and site exposures relative to an unexposed population. Generally, if the confidence interval around the relative risk includes one, cancer incidence rates for the two populations (exposed and unexposed) are not significantly different. Therefore, the DOD review concluded there was insufficient evidence to conclude that TCE exposures in drinking water were associated with an increase in non-Hodgkins lymphoma and thus, no slope factor should be calculated based on that study. Only one study had non-Hodgkins lymphoma associated with TCE exposure.

The DOD review also criticized the study on which the low end of EPA's proposed slope factor range was based, which was an inhalation study where TCE exposures were associated with an increase in kidney cancer. The DOD noted that the particular study has been highly criticized in the open literature and concluded that without that study, the remaining data do not confirm an increased relative risk of kidney cancer from TCE exposure (AFIERA, 2001).

Because of the uncertainty surrounding the new proposed slope factor range, and because of the criticisms the health assessment document has received, currently the oral and inhalation slope factors derived by the California EPA (CalEPA) Office of Environmental Health Hazard Assessment (OEHHA) for are generally being recommended for use in risk assessment. The slope factors derived by OEHHA are an inhalation slope factor of 0.007 $(mg/kg\text{-}day)^{-1}$, as presented in OEHHA (2002) and an oral slope factor of 0.013 $(mg/kg\text{-}day)^{-1}$, as presented in OEHHA (1999).

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OEHHA, 2002, *Air Toxics Hot Spots Program Risk Assessment Guidelines. Part II: Technical Support Document for Describing Available Cancer Potency Factors*, dated December 2002, California Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Section, Sacramento, California.

TRITIUM

Tritium (H-3) is the only radioactive isotope of hydrogen. The most common forms are tritium gas and tritium oxide or "tritiated water." Tritium has a high specific activity and is produced both naturally and artificially. Tritium emits low-energy beta particles as it decays and has a half-life of 12 years (ANL, 2007).

The primary concern for tritium exposure is only if it ingested (especially in the form of tritiated water) because it cannot penetrate deeply into tissue or travel far in air. Once ingested, tritium may cause cell damage and lead to cancer. Ionizing radiation has been shown to be a human carcinogen, and the EPA classifies all radionuclides as Group A carcinogens (EPA, 2001). Based on the carcinogenicity of ionizing radiation, cancer slope factors have been derived for tritium. The slope factor s for tritium are 5.1×10^{-14} risk per pCi for water ingestion, 1.4×10^{-13} risk per pCi for food ingestion, 2.2×10^{-13} risk per pCi for soil ingestion, 5.6×10^{-14} risk per pCi for vapor inhalation, and 2×10^{-13} risk per pCi for particulate inhalation (EPA, 2001).

References

ANL, 2007, *Radiological and Chemical Fact Sheets to Support Health Risk Analysis for Contaminated Areas*, dated March 2007, Argonne National Laboratory, Environmental Assessment Division, Argonne, Illinois.

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URANIUM

Uranium is an actinide element that occurs naturally as one of three radioactive isotopes: uranium-238, uranium-235, and uranium-234. All three natural uranium isotopes decay by alpha particle emission. The term "natural uranium" refers to uranium that has a uranium isotopic composition reflecting the natural abundance of uranium-238, uranium-235, and uranium-234, as presented in the table below. This distinguishes natural uranium from other anthropogenic uranium isotope mixtures. The term "enriched uranium" refers to isotope mixtures that contain a higher percentage of the fissionable isotope, uranium-235 (and also uranium-234, a byproduct of the enrichment process), and a lower percentage of uranium-238 than natural uranium. Enriched uranium is produced as fuel for reactors and nuclear fission weapons. Other isotopes of uranium are produced by humans in controlled or uncontrolled (explosive) nuclear reactions (e.g., isotopes uranium-227 through uranium-240).

Natural Abundances and Radioactive Half-Lives of Uranium Isotopes

Uranium Isotope	Natural Abundance	Radioactive Half-Life (years)
Uranium-238	99.27%	4.46×10^9
Uranium-235	0.72%	7.04×10^8
Uranium-234	0.0055%	2.45×10^5

Note: Values from (EPA/600/P-95-002FA).

The primary radiological concern related to uranium is the risk associated with exposure to ionizing radiation, which will vary with the dose of uranium, the isotopic form, and other factors that affect uranium bioavailability, tissue distribution, and retention. Ionizing radiation has been shown to be a carcinogen in humans, and the EPA classifies all radionuclides as Group A carcinogens (EPA, 1997). Based on the carcinogenicity of ionizing radiation, cancer slope factors have been derived for the naturally occurring isotopes of uranium (EPA, 1997). Natural uranium has a relatively low radioactivity (less than 1 μCi/g) compared to enriched uranium, which has a higher abundance of the more highly radioactive isotopes uranium-235 and uranium-234 and can have a radioactivity that is approximately 100 times that of natural uranium. Therefore, the radiological hazard of enriched uranium can be considerably greater than that of natural uranium.

Uranium occurs naturally predominantly in valence states +4 and +6, although valence states +2, +3, and +5 can also occur naturally or be produced by humans (EPA, 1988). Uranium compounds vary widely in their water solubility. Uranium oxides are practically soluble in water while salts of tetravalent (+4) and hexavalent (+6) uranium can be highly water soluble (Gindler, 1973). Differences in water solubility and other chemical properties can be expected to give rise to differences in bioavailability and dose-response relationships when intakes occur through either the inhalation or oral routes (EPA, 1988).

Non-cancer (RfD and RfC) and cancer risk values for natural uranium are not listed in the IRIS database (EPA, 1998) or in the *Health Effects Assessment Summary Tables* (HEAST) (EPA, 1997). Based on the NOAEL of 0.2 mg U/kg-day (Gilman et al., 1998a; 1998b; and 1998c), a provisional chronic oral RfD of 2 x 10^{-4} mg/kg-day was estimated by the Superfund Technical Support Center (2001). A chronic oral RfD of 3 x 10^{-3} mg U/kg-day for soluble uranium salts is in found in the IRIS database (EPA, 2007).

The EPA developed a health effects assessment for natural uranium (EPA, 1988) and drinking water standards for uranium (EPA, 2000). The ATSDR (1997) derived a chronic-duration inhalation minimum risk level (MRL) for uranium of 1.0 x 10^{-3} mg U/m^3 and an intermediate-duration oral MRL of 1.0 x 10^{-3} mg U/kg-day.

Derivation of a Provisional Oral RfD for Soluble Uranium Salts

Non-cancer (RfD and RfC) and cancer risk values for natural uranium are not listed on IRIS or in HEAST (EPA, 2007,; 1997; 2001). A chronic oral RfD of 3 x 10^{-3} mg U/kg-day for soluble uranium salts is on IRIS (EPA, 2007). The available data on the inhalation toxicology of natural uranium compounds do not provide an adequate basis for deriving inhalation RfCs (EPA, 2007). The most substantial gap in the data are the lack of chronic inhalation studies of adequate quality that examine the respiratory tract as well as other suspected target organs such as the kidney. Based on chronic studies of natural uranium dioxide, it is possible that chronic exposures to 5 mg U/m^3 may have yielded either a chemical and/or radiological dose to the lung that was sufficient to induce injury to the respiratory tract.

Derivation of Provisional Cancer Risk Values for Inhalation of Soluble Uranium Salts

An increase risk of lung cancer has been observed in populations of uranium miners and uranium processing workers. However, this excess risk is thought to result, at least in part, if not primarily, from radiological exposures. Data are not adequate to assess the nonradiological carcinogenicity of natural uranium. The EPA classifies all radionuclides, including uranium, as Group A carcinogens (EPA, 1997). Based on the carcinogenicity of ionizing radiation, cancer slope factors have been derived for the naturally occurring isotopes of uranium.

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APPENDIX A

ATTACHMENT 6

GROUNDWATER AND SOIL RISK CALCULATIONS

ATTACHMENT 6
TABLE OF CONTENTS

216-Z-9 TRENCH–RESIDENTIAL EXPOSURES TO SOIL

216-Z-9 TRENCH–WELL DRILLER EXPOSURES TO SOIL

216-A-8 CRIBRESIDENTIAL EXPOSURES TO SOIL

Residential Farmer Exposures to Groundwater – Nonradionuclides

Table 6-1. Residential Exposures (Nonradioactive Chemicals).

Ingestion of Groundwater

Future

Exposure Medium: Groundwater
Exposure Point: Drinking Water
Receptor Population: Resident
Receptor Age: Children and Adults

Non-Cancer Hazard = CW x SIFnc / RfD
Cancer Risk = CW x SIFc x CSF

Parameter	Unit	RME Child	RME Adult
Chemical Conc'n in Water (CW)	ug/L	chem-specific	chem-specific
Ingestion Rate of Water (IR)	L/day	1	2
Exposure frequency (EF)	days/yr	350	350
Exposure duration (ED)	years	6	24
Body weight (BW)	kg	15	70
Conversion Factor (CF)	mg/ug	1.00E-03	1.00E-03
Averaging time (non-cancer) (ATnc)	days	2,190	8,760
Averaging time (cancer) (ATc)	days	25,550	25,550
SIFnc = (IR*EF*ED*CF)/(BW*ATnc)	L-mg/ug-kg-d	6.39E-05	2.74E-05
IngFadj (Ingestion Adjusted Factor) = (IRch*EDch/BWch)+ (IRa*EDa/BWa)	L-year/hr-kg	1.09	1.09
SIFc = (IngFadj*EF*CF)/ATc	L-mg/ug-kg-d	1.49E-05	1.49E-05

Chemical	RfDo (mg/kg-d)	CSFo $(mg/kg\text{-}d)^{-1}$
Carbon Tetrachloride	7.00E-04	1.30E-01
Chloroform	1.00E-02	--
Chromium III	1.50E+00	--
Chromium VI (groundwater)	3.00E-03	--
Methylene Chloride	6.00E-02	7.50E-03
Nitrate	1.60E+00	--
PCE	1.00E-02	5.40E-01
TCE	3.00E-04	1.30E-02
Uranium	3.00E-03	--

Total Inorganics Chemical	90th Percentile CW (ug/L)	Intake$_{nc}$ child (mg/kg-d)	Intake$_{nc}$ adult (mg/kg-d)	Intake$_{c}$ lifetime (mg/kg-d)	HQ child	HQ adult	Cancer Risk lifetime
Carbon Tetrachloride	2,900.00	1.85E-01	7.95E-02	4.31E-02	264.840	113.503	5.6E-03
Chloroform	24.00	1.53E-03	6.58E-04	3.57E-04	0.153	0.066	--
Total Chromium	130.00	8.31E-03	3.56E-03	1.93E-03	0.006	0.002	--
Chromium VI	203.40	1.30E-02	5.57E-03	3.03E-03	4.334	1.858	--
Methylene Chloride	2.73	1.75E-04	7.49E-05	4.07E-05	0.003	0.001	3.0E-07
Nitrate	81,050.00	5.18E+00	2.22E+00	1.21E+00	3.238	1.388	--
PCE	2.50	1.60E-04	6.85E-05	3.72E-05	0.016	0.007	2.0E-05
TCE	10.90	6.97E-04	2.99E-04	1.62E-04	2.323	0.995	2.1E-06
Uranium	8.30	5.30E-04	2.27E-04	1.23E-04	0.177	0.076	--
Total					**275**	**118**	**5.6E-03**

Table 6-2. Residential Exposures (Nonradioactive Chemicals).

Inhalation of Vapor

Future

Exposure Medium: Groundwater
Exposure Point: Drinking Water
Receptor Population: Resident
Receptor Age: Children and Adults

Non-Cancer Hazard = CA x SIFnc x VFw / RfD
Cancer Risk = CA x SIFc x VFw x CSF

Parameter	Unit	RME Child	RME Adult
Chemical Conc'n in Water (CW)	ug/L	chem-specific	chem-specific
Inhalation Rate (InhR)	m^3/day	10	20
Exposure Frequency (EF)	days/yr	350	350
Exposure Duration (ED)	years	6	24
Body Weight (BW)	kg	15	70
Conversion Factor (CF)	mg/ug	1.0E-03	1.0E-03
Averaging Time (non-cancer) (ATnc)	days	2,190	8,760
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc = (InhR*EF*ED*CF)/(BW*ATnc)	m^3-mg/ug-kg-day	6.39E-04	2.74E-04
InhFadj (Inhalation Adjusted Factor) = (InhRch*EDch/BWch) + (InhRa*EDa/BWa)	m^3-yr/hr-kg	1.09E+01	1.09E+01
SIFc = (InhFadj*EF*CF)/ATc	m^3-mg/ug-kg-day	1.49E-04	1.49E-04

Chemical	RfDi (mg/kg-d)	CSFi $(mg/kg-d)^{-1}$	VFw[a] (L/m^3)
Carbon Tetrachloride	--	5.3E-02	5.0E-01
Chloroform	1.3E-02	8.1E-02	5.0E-01
Chromium III	--	--	--
Chromium VI (groundwater)	2.9E-05	2.9E+02	--
Methylene Chloride	8.6E-01	1.6E-03	5.0E-01
Nitrate	--	--	--
PCE	1.1E-01	2.1E-02	5.0E-01
TCE	1.1E-02	7.0E-03	5.0E-01
Uranium	--	--	--

[a]A volatilization factor (VFw) of 0.5 is only applicable for volatile chemicals.

Dissolved Inorganics Chemical	90th Percentile CW (ug/L)	$Intake_{nc}$ child (mg/kg-d)	$Intake_{nc}$ adult (mg/kg-d)	$Intake_c$ lifetime (mg/kg-d)	HQ child	HQ adult	Cancer Risk lifetime
Carbon Tetrachloride	2,900.00	9.27E-01	3.97E-01	2.16E-01	--	--	1.1E-02
Chloroform	24.00	7.67E-03	3.29E-03	1.78E-03	0.59	0.25	1.4E-04
Total Chromium	130.00	--	--	--	--	--	--
Chromium VI	203.40	--	--	--	--	--	--
Methylene Chloride	2.73	8.74E-04	3.75E-04	2.03E-04	0.0010	0.00044	3.3E-07
Nitrate	81,050.00	--	--	--	--	--	--
PCE	2.50	7.99E-04	3.42E-04	1.86E-04	0.0073	0.0031	3.9E-06
TCE	10.90	3.48E-03	1.49E-03	8.11E-04	0.32	0.14	5.7E-06
Uranium	8.3	--	--	--	--	--	--
Total					**0.92**	**0.39**	**1.2E-02**

Table 6-3a. Residential Exposures (Nonradioactive Chemicals).

Intermediate Dermal Spreadsheet

Exposure Medium: Groundwater
Exposure Point: Drinking Water
Receptor Population: Resident
Receptor Age: Children and Adults

Exposure Parameters		Units
Fraction absorbed	FA	unitless
Dermal permeability coefficient	PC	cm/hr
Concentration in surface water	CW	mg/m^3
Lag time per event	T event	hour/event
Time to reach steady state	t*	hours
Event duration	t event	hour/event
Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis	B	unitless
Absorbed dose per event	DA event	mg/cm2-event

Formulas Used to Calculate Absorbed Dose per Event (DAevent):

ORGANIC CHEMICALS:

If $t_{event} \leq t^*$, then $DA_{event} = 2\ FA \times PC \times Cw\ (6 \times T_{event} \times t_{event}/Pi)^{0.5}$

If $t_{event} > t^*$, then $DA_{event} = FA \times PC \times Cw\ [(t_{event}/1 + B) + (2 \times Tau_{event}) \times (1 + 3B + 3B^2/(1 + B)^2]$

INORGANIC CHEMICALS:

$DA_{event} = PC \times Cw \times t_{event}$

Chemical	FA	PC	Cw	T_{event}	t*	t_{event} hr/event		Pi	B	Daevent mg/cm^2-event	
	unitless	cm/hr	mg/cm^3	hr/event	hours	Adult	Child	unitless	unitless	Adult	Child
Carbon Tetrachloride	1	1.60E-02	2.90E-03	0.78	1.86	0.17	0.33	3.14	0.1	4.67E-05	6.51E-05
Chloroform	1	6.80E-03	2.40E-05	0.5	1.19	0.17	0.33	3.14	0	1.32E-07	1.83E-07
Total Chromium	--	0.001	1.30E-04	--	--	0.17	0.33	3.14	--	2.21E-08	4.29E-08
Chromium VI	--	2.00E-03	2.03E-04	--	--	0.17	0.33	3.14	--	6.92E-08	1.34E-07
Methylene Chloride	1	3.50E-03	2.73E-06	0.32	0.76	0.17	0.33	3.14	0	6.17E-09	8.60E-09
Nitrate	--	--	8.11E-02	--	--	0.17	0.33	3.14	--	--	--
PCE	1	3.30E-02	2.50E-06	0.91	2.18	0.17	0.33	3.14	0.2	8.97E-08	1.25E-07
TCE	1	1.20E-02	1.09E-05	0.58	1.39	0.17	0.33	3.14	0.1	1.14E-07	1.58E-07
Uranium	--	2.00E-03	8.3E-06	--	--	0.17	0.33	3.14	--	2.82E-09	5.47E-09

Table 6-3b. Residential Exposures (Nonradioactive Chemicals).

Dermal Contact with Groundwater
Future

Exposure Medium: Groundwater
Exposure Point: Drinking Water
Receptor Population: Resident
Receptor Age: Children and Adults

Non-Cancer HQ =DAevent x SIFnc / RfD
Cancer Risk = DAevent x SIFc x CSF

Parameter	Units	RME Adult	RME Child
Absorbed dose per event (DAevent)	(mg/cm^2-event)	chem-specific	chem-specific
Exposure Frequency (EF)	days/yr	350	350
Exposure Duration (ED)	years	24	6
Event Frequency (EV)	events/day	1	1
Surface Area Available for Contact (SA)	cm^2	18,000	6,600
Body Weight (BW)	days	70	15
Averaging Time (non-cancer) (ATnc)	days	8,760	2,190
Averaging Time (cancer) (ATc)		25,550	25,550
SIFnc(child) = ((EF*EDc*SAc)/(BWc*ATnc-c))	ev-cm^2/kg-d	2.47E+02	4.22E+02
DFadj (Dermal Adjusted Factor) = (EDc*EFc*EVc*SAc/BWc)+(EDa*EFa*EVa*SAa/BWa)	ev-cm^2/kg	3.08E+06	
SIFc(child/adult) = DFadj/ATc	ev-cm^2/kg-d	1.21E+02	

Chemical	RfD-D (mg/kg-d)	CSF-D $(mg/kg\text{-}d)^{-1}$
Carbon Tetrachloride	7.0E-04	1.3E-01
Chloroform	1.0E-02	--
Chromium III	2.0E-02	--
Chromium VI (groundwater)	7.5E-05	--
Methylene Chloride	6.0E-02	7.5E-03
Nitrate	--	--
PCE	1.0E-02	5.4E-01
TCE	3.0E-04	1.3E-02
Uranium	3.0E-03	--

Chemical	90th Percentile DA event (mg/cm^2-event) child	DA event (mg/cm^2-event) adult	$Intake_{nc}$ child (mg/kg-d)	$Intake_{nc}$ adult (mg/kg-d)	$Intake_c$ child/adult (mg/kg-d)	HQ child	HQ adult	Risk child/adult
Carbon Tetrachloride	6.51E-05	4.67E-05	2.75E-02	1.15E-02	5.64E-03	39	16	7.33E-04
Chloroform	1.83E-07	1.32E-07	7.73E-05	3.24E-05	1.59E-05	0.0077	0.0032	--
Total Chromium	4.29E-08	2.21E-08	1.81E-05	5.45E-06	2.67E-06	0.00093	0.00028	--
Chromium VI	1.34E-07	6.92E-08	5.66399E-05	1.71E-05	8.35E-06	0.76	0.23	--
Methylene Chloride	8.60E-09	6.17E-09	3.63E-06	1.52E-06	7.45E-07	0.000060	0.000025	5.59E-09
Nitrate	--	--	--	--	--	--	--	--
PCE	1.25E-07	8.97E-08	5.27E-05	2.21E-05	1.08E-05	0.0053	0.0022	5.85E-06
TCE	1.58E-07	1.14E-07	6.67E-05	2.80E-05	1.37E-05	0.22	0.09	1.78E-07
Uranium	5.47E-09	2.82E-09	2.31E-06	6.95E-07	3.40E-07	0.00077	0.00023	--
Total						40	17	7.4E-04

Table 6-4. Residential Exposures (Nonradioactive Chemicals).

Inhalation of Vapor
Future

Exposure Medium: Groundwater
Exposure Point: Irrigation Water
Receptor Population: Resident
Receptor Age: Adults

Non-Cancer Hazard = CA x SIFnc x VFw / RfD
Cancer Risk = CA x SIFc x VFw x CSF

Parameter	Unit	RME Adult
Chemical Conc'n of Water (CW)	ug/L	chem-specific
Inhalation Rate (InhR)	m^3/hr	1.5
Exposure Time (ET)	hr/day	2
Exposure Frequency (EF)	days/yr	90
Exposure Duration (ED)	years	30
Conversion Factor (CF)	mg/ug	1.0E-03
Body Weight (BW)	kg	70
Averaging Time (non-cancer) (ATnc)	days	10,950
Averaging Time (cancer) (ATc)	days	25,550
SIFnc = (InhR*ET*EF*ED*CF)/(BW*ATnc)	m^3-mg/ug-kg-day	1.06E-05
SIFc = (InhR*ET*EF*ED*CF)/(BW*ATc)	m^3-mg/ug-kg-day	4.53E-06

Chemical	RfDi (mg/kg-d)	CSFi $(mg/kg\text{-}d)^{-1}$	VFw[a] (L/m^3)
Carbon Tetrachloride	--	5.3E-02	2.0E-02
Chloroform	1.3E-02	8.1E-02	2.0E-01
Chromium III	--	--	--
Chromium VI (groundwater)	2.9E-05	2.9E+02	--
Methylene Chloride	8.6E-01	1.6E-03	2.0E-02
Nitrate	--	--	--
PCE	1.1E-01	2.1E-02	2.0E-02
TCE	1.1E-02	7.0E-03	2.0E-02
Uranium	--	--	--

[a]A volatilization factor (VFw) of 0.02 is only applicable for volatile chemicals.

Dissolved Inorganics Chemical	90th Percentile CW (ug/L)	Intake$_{nc}$ adult (mg/kg-d)	Intake$_c$ adult (mg/kg-d)	HQ adult	Cancer Risk adult
Carbon Tetrachloride	2,900	6.13E-04	2.63E-04	--	1.4E-05
Chloroform	24	5.07E-05	2.17E-05	0.00390	1.8E-06
Total Chromium	130	--	--	--	--
Chromium VI	203	--	--	--	--
Methylene Chloride	3	5.78E-07	2.48E-07	0.0000007	4.0E-10
Nitrate	81,050	--	--	--	--
PCE	3	5.28E-07	2.26E-07	0.0000048	4.8E-09
TCE	11	2.30E-06	9.87E-07	0.00021	6.9E-09
Uranium	8	--	--	--	--
Total				0.0041	1.6E-05

Table 6-5a. Residential Exposures (Nonradioactive Chemicals).

Intermediate Dermal Spreadsheet

Exposure Medium: Groundwater
Exposure Point: Irrigation Water
Receptor Population: Resident
Receptor Age: Adults

Exposure Parameters		Units
Fraction absorbed	FA	unitless
Dermal permeability coefficient	PC	cm/hr
Concentration in surface water	CW	mg/m^3
Lag time per event	T event	hour/event
Time to reach steady state	t*	hours
Event duration	t event	hour/event
Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis.	B	unitless
Absorbed dose per event	DA event	mg/cm^2-event

Formulas Used to Calculate Absorbed Dose per Event (DAevent):

ORGANIC CHEMICALS:

If $t_{event} \leq t^*$, then $DA_{event} = 2\ FA \times PC \times Cw\ (6 \times T_{event} \times t_{event}/Pi)^{0.5}$

If $t_{event} > t^*$, then $DA_{event} = FA \times PC \times Cw\ [(t_{event}/1 + B) + (2 \times Tau_{event}) \times (1 + 3B + 3B^2/(1 + B)^2]$

INORGANIC CHEMICALS:

$DA_{event} = PC \times Cw \times t_{event}$

Chemical	FA	PC	Cw	T_{event}	t*	t_{event} hr/event		Pi	B	Daevent mg/cm^2-event	
	unitless	cm/hr	mg/cm^3	hr/event	hours	Adult	Child	unitless	unitless	Adult	Child
Carbon Tetrachloride	1	1.60E-02	2.90E-03	0.78	1.86	2	--	3.14	0.1	1.64E-04	--
Chloroform	1	6.80E-03	2.40E-05	0.5	1.19	2	--	3.14	0	4.90E-07	--
Total Chromium	--	0.001	1.30E-04	--	--	2	--	3.14	--	2.60E-07	--
Chromium VI	--	2.00E-03	2.03E-04	--	--	2	--	3.14	--	8.14E-07	--
Methylene Chloride	1	3.50E-03	2.73E-06	0.32	0.76	2	--	3.14	0	2.53E-08	--
Nitrate	--	--	8.11E-02	--	--	2	--	3.14	--	--	--
PCE	1	3.30E-02	2.50E-06	0.91	2.18	2	--	3.14	0.2	3.08E-07	--
TCE	1	1.20E-02	1.09E-05	0.58	1.39	2	--	3.14	0.1	4.05E-07	--
Uranium	--	2.00E-03	8.30E-06	--	--	2	--	3.14	--	3.32E-08	--

Table 6-5b. Residential Exposures (Nonradioactive Chemicals).

Dermal Contact with Groundwater
Future

Exposure Medium: Groundwater
Exposure Point: Irrigation Water
Receptor Population: Resident
Receptor Age: Adults

Non-Cancer HQ =DAevent x SIFnc / RfD
Cancer Risk = DAevent x SIFc x CSF

Parameter	Units	RME Adult
Absorbed dose per event (DAevent)	(mg/cm^2-event)	chem-specific
Exposure Frequency (EF)	days/yr	90
Exposure Duration (ED)	years	30
Event Frequency (EV)	events/day	1
Surface Area Available for Contact (SA)	cm^2	1,933
Body Weight (BW)	days	70
Averaging Time (non-cancer) (ATnc)	days	10,950
Averaging Time (cancer) (ATc)		25,550
SIFnc(adult) = ((EF*ED*EV*SA)/(BW*ATnc))	ev-cm^2/kg-d	6.81E+00
SIFc(adult) = ((EF*ED*EV*SA)/(BW*ATc))	ev-cm^2/kg-d	2.92E+00

Chemical	RfD-D (mg/kg-d)	CSF-D $(mg/kg\text{-}d)^{-1}$
Carbon Tetrachloride	7.0E-04	1.3E-01
Chloroform	1.0E-02	--
Chromium III	2.0E-02	--
Chromium VI (groundwater)	7.5E-05	--
Methylene Chloride	6.0E-02	7.5E-03
Nitrate	--	--
PCE	1.0E-02	5.4E-01
TCE	3.0E-04	1.3E-02
Uranium	3.0E-03	--

	90th Percentile				
Chemical	DA event (mg/cm^2-event) adult	$Intake_{nc}$ adult (mg/kg-d)	$Intake_c$ adult (mg/kg-d)	HQ adult	Risk adult
Carbon Tetrachloride	1.64E-04	1.12E-03	4.78E-04	1.6	6.22E-05
Chloroform	4.90E-07	3.33E-06	1.43E-06	0.00033	--
Total Chromium	2.60E-07	1.77E-06	7.59E-07	0.000091	--
Chromium VI	8.14E-07	5.5398E-06	2.37E-06	0.074	--
Methylene Chloride	2.53E-08	1.72E-07	7.37E-08	0.0000029	5.53E-10
Nitrate	--	--	--	--	--
PCE	3.08E-07	2.10E-06	8.98E-07	0.00021	4.85E-07
TCE	4.05E-07	2.75E-06	1.18E-06	0.0092	1.53E-08
Uranium	3.32E-08	2.26E-07	9.68E-08	0.000075	--
Total				1.7	6.3E-05

Table 6-6. Residential Exposures (Nonradioactive Chemicals).

Ingestion of Plant Tissue
Future

Exposure Medium: Groundwater (used for irrigation)
Exposure Point: Fruits and Vegetables
Receptor Population: Resident
Receptor Age: Adults

Non-Cancer Hazard = CTi x SIFnc / RfD
Cancer Risk = CTi x SIFc x CSF

Parameter	Unit	RME child/adult
Chemical Conc'n in Tissue (CTi)	mg/kg	chem-specific
Ingestion Rate of Plant Tissue (IR)	g/kg-day	4.6
Fraction of Plant from Contaminated Source (FC)	unitless	1
Exposure Frequency (EF)	days/yr	350
Exposure Duration (ED)	years	30
Conversion Factor (CF)	kg/g	1.00E-03
Averaging Time (non-cancer) (ATnc)	days	10,950
Averaging Time (cancer) (ATc)	days	25,550
SIFnc = (IR*FC*EF*ED*CF)/(Atnc*BW)	$(day)^{-1}$	4.41E-03
SIFc = (FC*EF*CF/ATc)*(IRc*Edc/BWc+IRa*Eda/BWa)	$(day)^{-1}$	1.89E-03

Chemical	RfDo (mg/kg-d)	CSFo $(mg/kg\text{-}d)^{-1}$
Carbon Tetrachloride	7.0E-04	1.3E-01
Chloroform	1.0E-02	--
Chromium III	1.5E+00	--
Chromium VI (groundwater)	3.0E-03	--
Methylene Chloride	6.0E-02	7.5E-03
Nitrate	1.6E+00	--
PCE	1.0E-02	5.4E-01
TCE	3.0E-04	1.3E-02
Uranium	3.0E-03	--

	90th Percentile				
Chemical	CTi (mg/kg)	$Intake_{nc}$ child/adult (mg/kg-d)	$Intake_c$ lifetime (mg/kg-d)	HQ child/adult	Cancer Risk lifetime
Carbon Tetrachloride	5.62E+01	2.48E-01	1.06E-01	354	1.4E-02
Chloroform	7.86E-01	3.47E-03	1.49E-03	0.35	--
Total Chromium	1.68E+00	7.42E-03	3.18E-03	0.0049	--
Chromium VI	2.63E+00	1.16E-02	4.98E-03	4	--
Methylene Chloride	1.77E-01	7.81E-04	3.35E-04	0.013	2.5E-06
Nitrate	--	--	--	--	--
PCE	3.97E-02	1.75E-04	7.50E-05	0.018	4.1E-05
TCE	2.59E-01	1.14E-03	4.90E-04	4	6.4E-06
Uranium	1.08E-01	4.76E-04	2.04E-04	0.16	--
Total				362	1.4E-02

Table 6-7. Residential Exposures (Nonradioactive Chemicals).

Ingestion of Plant Tissue
Future

Exposure Medium: Garden Soil
Exposure Point: Fruits and Vegetables
Receptor Population: Resident
Receptor Age: Adults

Non-Cancer Hazard = CTi x SIFnc / RfD
Cancer Risk = CTi x SIFc x CSF

Parameter	Unit	RME child/adult
Chemical Conc'n in Tissue (CTi)	mg/kg	chem-specific
Ingestion Rate of Plant Tissue (IR)	g/day	4.6
Fracton of Plant from Contaminated Source (FC)	unitless	1
Exposure Frequency (EF)	days/yr	350
Exposure Duration (ED)	years	30
Conversion Factor (CF)	kg/g	1.00E-03
Averaging Time (non-cancer) (ATnc)	days	10,950
Averaging Time (cancer) (ATc)	days	25,550
SIFnc = (IR*FC*EF*ED*CF)/(Atnc*BW)	$(day)^{-1}$	4.41E-03
SIFc = (FC*EF*CF/ATc)*(IRc*Edc/BWc+IRa*Eda/BWa)	$(day)^{-1}$	1.89E-03

Chemical	RfDo (mg/kg-d)	CSFo $(mg/kg\text{-}d)^{-1}$
Carbon Tetrachloride	7.0E-04	1.3E-01
1,2-Dibromo-3-chloropropane	2.0E-04	8.0E-01
Cadmium	1.0E-03	--
Manganese	7.0E-02	--
Thallium	6.6E-05	--

Chemical	90th Percentile CTi (mg/kg)	Intake$_{nc}$ child/adult (mg/kg-d)	Intake$_c$ lifetime (mg/kg-d)	HQ child/adult	Cancer Risk lifetime
Z-9 Trench Soil					
Carbon Tetrachloride	5.52	2.43E-02	1.04E-02	35	1.4E-03
1,2-Dibromo-3-chloropropane	0.037	1.63E-04	6.99E-05	1	5.6E-05
Cadmium	0.83	3.68E-03	1.58E-03	4	--
Manganese	29.59	1.31E-01	5.59E-02	2	--
Total				41	1.4E-03
A-8 Soil					
Thallium	0.05	2.21E-04	9.45E-05	3	--
Total				3	--

Table 6-8. Residential 1 Exposures (Nonradioactive Chemicals).

Ingestion of Beef Tissue

Future

Exposure Medium: Groundwater (used for watering livestock)
Exposure Point: Beef Cattle
Receptor Population: Resident
Receptor Age: Adults

Non-Cancer Hazard = CTi x SIFnc / RfD
Cancer Risk = CTi x SIFc x CSF

Parameter	Unit	RME child/adult
Chemical Conc'n in Tissue (CTi)	mg/kg	chem-specific
Ingestion Rate of Beef Tissue (IR)	g/day	2.41
Fracton of Plant from Contaminated Source (FC)	unitless	1
Exposure Frequency (EF)	days/yr	350
Exposure Duration (ED)	years	30
Conversion Factor (CF)	kg/g	1.00E-03
Averaging Time (non-cancer) (ATnc)	days	10,950
Averaging Time (cancer) (ATc)	days	25,550
SIFnc = (IR*FC*EF*ED*CF)/(Atnc*BW)	$(day)^{-1}$	2.31E-03
SIFc = (FC*EF*CF/ATc)*(IRc*Edc/BWc+IRa*Eda/BWa)	$(day)^{-1}$	9.90E-04

Chemical	RfDo (mg/kg-d)	CSFo $(mg/kg\text{-}d)^{-1}$
Carbon Tetrachloride	7.0E-04	1.3E-01
Chloroform	1.0E-02	--
Chromium III	1.5E+00	--
Chromium VI (groundwater)	3.0E-03	--
Methylene Chloride	6.0E-02	7.5E-03
Nitrate	1.6E+00	--
PCE	1.0E-02	5.4E-01
TCE	3.0E-04	1.3E-02
Uranium	3.0E-03	--

Chemical	90th Percentile				
	CTi (mg/kg)	$Intake_{nc}$ child/adult (mg/kg-d)	$Intake_{c}$ lifetime (mg/kg-d)	HQ child/adult	Cancer Risk lifetime
Carbon Tetrachloride	1.38E-02	3.18E-05	1.36E-05	0.045	1.8E-06
Chloroform	2.45E-05	5.66E-08	2.43E-08	0.0000057	--
Total Chromium	2.40E-01	5.55E-04	2.38E-04	0.00037	--
Chromium VI	3.76E-01	8.69E-04	3.72E-04	0.29	--
Methylene Chloride	9.92E-07	2.29E-09	9.82E-10	0.000000038	7.4E-12
Nitrate	--	--	--	--	--
PCE	3.77E-05	8.70E-08	3.73E-08	0.0000087	2.0E-08
TCE	2.39E-05	5.52E-08	2.37E-08	0.00018	3.1E-10
Uranium	5.13E-04	1.19E-06	5.08E-07	0.00040	--
Total				0.34	1.8E-06

Table 6-9. Residential Exposures (Nonradioactive Chemicals).

Ingestion of Dairy Products
Future

Exposure Medium: Groundwater (used for watering livestock)
Exposure Point: Dairy Cattle
Receptor Population: Resident
Receptor Age: Adults

Non-Cancer Hazard = CMi x SIFnc / RfD
Cancer Risk = CMi x SIFc x CSF

Parameter	Unit	RME child
Chemical Conc'n in Tissue (CTi)	mg/kg	chem-specific
Ingestion Rate of Dairy (IR)	g/day	10
Fracton of Plant from Contaminated Source (FC)	unitless	1
Exposure Frequency (EF)	days/yr	350
Exposure Duration (ED)	years	30
Conversion Factor (CF)	kg/g	1.00E-03
Averaging Time (non-cancer) (ATnc)	days	10,950
Averaging Time (cancer) (ATc)	days	25,550
SIFnc = (IR*FC*EF*ED*CF)/(Atnc)	$(day)^{-1}$	9.59E-03
SIFc = (IR*FC*EF*CF/ATc)*(EDc+EDa)	$(day)^{-1}$	4.11E-03

Chemical	RfDo (mg/kg-d)	CSFo $(mg/kg-d)^{-1}$
Carbon Tetrachloride	7.0E-04	1.3E-01
Chloroform	1.0E-02	--
Chromium III	1.5E+00	--
Chromium VI (groundwater)	3.0E-03	--
Methylene Chloride	6.0E-02	7.5E-03
Nitrate	1.6E+00	--
PCE	1.0E-02	5.4E-01
TCE	3.0E-04	1.3E-02
Uranium	3.0E-03	--

Chemical	90th Percentile				
	CM (mg/kg)	$Intake_{nc}$ child/adult (mg/kg-d)	$Intake_c$ lifetime (mg/kg-d)	HQ child/adult	Cancer Risk lifetime
Carbon Tetrachloride	6.49E-03	6.23E-05	2.67E-05	0.09	3.5E-06
Chloroform	1.14E-05	1.09E-07	4.69E-08	0.000011	--
Total Chromium	4.04E-04	3.87E-06	1.66E-06	0.0000026	--
Chromium VI	6.32E-04	6.06E-06	2.60E-06	0.0020	--
Methylene Chloride	4.54E-07	4.36E-09	1.87E-09	0.000000073	1.4E-11
Nitrate	--	--	--	--	--
PCE	1.78E-05	1.71E-07	7.33E-08	0.000017	4.0E-08
TCE	1.12E-05	1.07E-07	4.61E-08	0.00036	6.0E-10
Uranium	1.03E-03	9.88E-06	4.23E-06	0.0033	--
Total				0.09	3.5E-06

Table 6-10. Summary of Cancer Risks Associated with Various Groundwater Concentrations for the Nonradionuclide COPCs Post-2150 Unrestricted Land Use–Residential Farmer. (2 sheets)

COPC	Groundwater Concentration (ug/L)	Tap Water				Irrigation			Meat	Plant	Milk
		Ingestion	Inhalation	Dermal	Total	Inhalation	Dermal	Total	Ingestion	Ingestion	Ingestion
90th Percentile Groundwater Concentration											
Carbon Tetrachloride	2,900	5.6E-03	1.1E-02	7.3E-04	1.8E-02	1.4E-05	6.2E-05	7.5E-05	1.8E-06	1.4E-02	3.5E-06
Chloroform	24	[a]	1.4E-04	[a]	1.4E-04	1.8E-06	[a]	1.6E-07	[a]	[a]	[a]
Chromium III	130	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
Chromium VI (groundwater)	203.4	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
Methylene Chloride	2.734	3.0E-07	3.3E-07	5.6E-09	6.4E-07	4.0E-10	5.5E-10	9.1E-10	7.4E-12	2.5E-06	1.4E-11
Nitrate	81,050	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
PCE	2.5	2.0E-05	3.9E-06	5.8E-06	3.0E-05	4.8E-09	4.8E-07	4.9E-07	2.0E-08	4.1E-05	4.0E-08
TCE	10.9	2.1E-06	5.7E-06	1.78E-07	8.0E-06	6.9E-09	1.5E-08	2.2E-08	3.1E-10	6.4E-06	6.0E-10
Uranium	8.295	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
TOTAL		5.6E-03	1.2E-02	7.4E-04	1.8E-02	1.6E-05	6.3E-05	7.8E-05	1.8E-06	1.4E-02	3.5E-06
50th Percentile Groundwater Concentration											
Carbon Tetrachloride	505	9.8E-04	2.0E-03	1.3E-04	3.1E-03	2.4E-06	1.1E-05	1.3E-05	3.1E-07	2.4E-03	6.0E-07
Chloroform	6.4	[a]	3.9E-05	[a]	3.9E-05	4.7E-07	[a]	4.7E-07	[a]	[a]	[a]
Chromium III	10.3	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
Chromium VI (groundwater)	10.9	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
Methylene Chloride	0.185	2.1E-08	2.2E-08	3.8E-10	4.3E-08	2.7E-11	3.7E-11	6.4E-11	5.0E-13	1.7E-07	9.5E-13
Nitrate	21,900	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
PCE	0.36	2.9E-06	5.6E-07	8.4E-07	4.3E-06	6.8E-10	7.0E-08	7.1E-08	2.9E-09	5.8E-06	5.7E-09
TCE	1.7	3.3E-07	8.8E-07	2.8E-08	1.2E-06	1.1E-09	2.4E-09	3.5E-09	4.8E-11	9.9E-07	9.3E-11
Uranium	1.18	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
TOTAL		9.8E-04	2.0E-03	1.3E-04	3.1E-03	2.9E-06	1.1E-05	1.4E-05	3.1E-07	2.4E-03	6.1E-07

Table 6-10. Summary of Cancer Risks Associated with Various Groundwater Concentrations for the Nonradionuclide COPCs Post-2150 Unrestricted Land Use–Residential Farmer. (2 sheets)

COPC	Groundwater Concentration (ug/L)	Tap Water Ingestion	Tap Water Inhalation	Tap Water Dermal	Tap Water Total	Irrigation Inhalation	Irrigation Dermal	Irrigation Total	Meat Ingestion	Plant Ingestion	Milk Ingestion
25th Percentile Groundwater Concentration											
Carbon Tetrachloride	6.5	1.3E-05	2.6E-05	1.6E-06	4.0E-05	3.1E-08	1.4E-07	1.7E-07	4.0E-09	3.1E-05	7.8E-09
Chloroform	0.6	[a]	3.5E-06	[a]	3.5E-06	4.3E-08	[a]	4.3E-08	[a]	[a]	[a]
Chromium III	3.6	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
Chromium VI (groundwater)	7.0	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
Methylene Chloride	0.12	1.3E-08	1.4E-08	2.5E-10	2.8E-08	1.7E-11	2.4E-11	4.2E-11	3.2E-13	1.1E-07	6.1E-13
Nitrate	14,000	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
PCE	0.18	1.4E-06	2.8E-07	4.2E-07	2.1E-06	3.4E-10	3.5E-08	3.5E-08	1.5E-09	2.9E-06	2.8E-09
TCE	0.16	3.0E-08	8.1E-08	2.5E-09	1.1E-07	9.8E-11	2.2E-10	3.2E-10	4.4E-12	9.1E-08	8.5E-12
Uranium	0.81	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
TOTAL		1.4E-05	2.9E-05	2.1E-06	4.6E-05	7.4E-08	1.8E-07	2.5E-07	5.4E-09	3.4E-05	1.1E-08
Average Groundwater Concentration											
Carbon Tetrachloride	1,009	2.0E-03	4.0E-03	2.6E-04	6.2E-03	4.8E-06	2.2E-05	2.6E-05	6.2E-07	4.8E-03	1.2E-06
Chloroform	11	[a]	6.4E-05	[a]	6.4E-05	7.8E-07	[a]	7.8E-07	[a]	[a]	[a]
Chromium III	50	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
Chromium VI (groundwater)	75	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
Methylene Chloride	8.2	9.1E-07	9.7E-07	1.7E-08	1.9E-06	1.2E-09	1.7E-09	2.8E-09	2.2E-11	7.5E-06	4.2E-11
Nitrate	44,750	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
PCE	2.5	2.0E-05	3.9E-06	5.9E-06	3.0E-05	4.8E-09	4.9E-07	5.0E-07	2.0E-08	4.1E-05	4.0E-08
TCE	4.7	9.2E-07	2.5E-06	7.8E-08	3.5E-06	3.0E-09	6.7E-09	9.7E-09	1.3E-10	2.8E-06	2.6E-10
Uranium	10	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
TOTAL		2.0E-03	4.0E-03	2.6E-04	6.3E-03	5.6E-06	2.2E-05	2.8E-05	6.4E-07	4.9E-03	1.2E-06
UCL95 Groundwater Concentration											
Carbon Tetrachloride	1,491	2.9E-03	5.9E-03	3.8E-04	9.1E-03	7.2E-06	3.2E-05	3.9E-05	9.1E-07	7.1E-03	1.8E-06
Chloroform	19	[a]	1.1E-04	[a]	1.1E-04	1.4E-06	[a]	1.4E-06	[a]	[a]	[a]
Chromium III	74	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
Chromium VI (groundwater)	176	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
Methylene Chloride	20	2.2E-06	2.4E-06	4.1E-08	4.7E-06	2.9E-09	4.1E-09	7.0E-09	5.4E-11	1.8E-05	1.0E-10
Nitrate	63,187	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
PCE	5	3.9E-05	7.6E-06	1.1E-05	5.8E-05	9.3E-09	9.4E-07	9.5E-07	3.9E-08	7.9E-05	7.7E-08
TCE	7	1.4E-06	3.7E-06	1.2E-07	5.2E-06	4.5E-09	1.0E-08	1.5E-08	2.0E-10	4.2E-06	3.9E-10
Uranium	29	[a]	[a]	[a]	--	[a]	[a]	--	[a]	[a]	[a]
TOTAL		2.9E-03	6.0E-03	3.9E-04	9.3E-03	8.6E-06	3.3E-05	4.2E-05	9.5E-07	7.2E-03	1.9E-06

[a]Chemical not associated with carcinogenic effects through the pathways of exposure from groundwater.
--=no value to sum

Table 6-11. Summary of Non-Cancer Hazards Associated with Various Groundwater Concentrations for the Nonradionuclide COPCs Post-2150 Unrestricted Land Use–Residential Farmer. (2 sheets)

COPC	Groundwater Concentration (ug/L)	Tap Water								Irrigation			Meat		Plant		Dairy Products	
		Ingestion		Inhalation		Dermal		Total		Inhalation	Dermal	Total	Ingestion		Ingestion		Ingestion	
		Child	Adult	Child	Adult	Child	Adult	Child	Adult	Adult	Adult	Adult	Child	Adult	Child	Adult	Child	Adult
90th Percentile Groundwater Concentration																		
Carbon Tetrachloride	2,900.00	265	114	[b]	[b]	39	16	304	130	[b]	1.6	1.6	0.045	0.045	354	354	0.089	0.089
Chloroform	24	0.15	0.066	0.59	0.25	0.0077	0.0032	0.75	0.32	0.0039	0.00033	0.0042	0.0000057	0.0000057	0.35	0.35	0.000011	0.000011
Chromium III	130	0.0055	0.0024	[a]	[a]	0.00093	0.00028	0.0065	0.0027	[a]	0.000091	0.000091	0.00037	0.00037	0.0049	0.0049	0.0000026	0.0000026
Chromium VI (groundwater)	203.4	4	2	[a]	[a]	0.76	0.23	5.1	2.1	[a]	0.074	0.074	0.29	0.29	4	4	0.0020	0.0020
Methylene Chloride	2.734	0.0029	0.0012	0.0010	0.00044	0.000060	0.000025	0.0040	0.0017	0.00000067	0.0000029	0.0000035	0.000000038	0.000000038	0.013	0.013	0.000000073	0.000000073
Nitrate	81,050	3.24	1.39	[b]	[b]	[b]	[b]	3.2	1.4	[b]	[b]	--	[b]	[b]	[b]	[b]	[b]	[b]
PCE	2.5	0.016	0.0068	0.0073	0.0031	0.0053	0.0022	0.029	0.012	0.0000048	0.00021	0.00021	0.0000087	0.0000087	0.018	0.018	0.000017	0.000017
TCE	10.9	2	1	0.32	0.14	0.22	0.093	2.86	1.22	0.00021	0.0092	0.0094	0.00018	0.00018	3.8	3.8	0.00036	0.00036
Uranium	8.295	0.18	0.076	[a]	[a]	0.00077	0.00023	0.18	0.076	[a]	0.000075	0.000075	0.00040	0.00040	0.16	0.16	0.0033	0.0033
TOTAL		275	118	0.92	0.39	40	17	316	135	0.0041	1.7	1.7	0.34	0.34	362	362	0.095	0.095
50th Percentile Groundwater Concentration																		
Carbon Tetrachloride	505.00	46	20	[b]	[b]	6.8	2.9	53	23	[b]	0.28	0.28	0.0079	0.0079	62	62	0.015	0.015
Chloroform	6.4	0.041	0.018	0.16	0.067	0.0021	0.00086	0.20	0.086	0.00104	0.000089	0.00113	0.0000015	0.0000015	0.092	0.092	0.0000029	0.0000029
Chromium III	10.3	0.00044	0.00019	[a]	[a]	0.000074	0.000022	0.00051	0.00021	[a]	0.0000072	0.0000072	0.000029	0.000029	0.00039	0.00039	0.00000020	0.00000020
Chromium VI (groundwater)	10.9	0.23	0.10	[a]	[a]	0.040	0.012	0.27	0.11	[a]	0.0040	0.0040	0.016	0.016	0.21	0.21	0.00011	0.00011
Methylene Chloride	0.185	0.00020	0.000084	0.000069	0.000029	0.0000041	0.0000017	0.00027	0.00012	0.000000045	0.00000019	0.00000024	0.0000000026	0.0000000026	0.00088	0.00088	0.0000000049	0.0000000049
Nitrate	21,900	0.88	0.38	[b]	[b]	[b]	[b]	0.88	0.38	[b]	[b]	--	[b]	[b]	[b]	[b]	[b]	[b]
PCE	0.36	0.0023	0.0010	0.0010	0.00045	0.00076	0.00032	0.0041	0.0018	0.00000069	0.000030	0.000031	0.0000013	0.0000013	0.0025	0.0025	0.0000025	0.0000025
TCE	1.7	0.36	0.16	0.049	0.021	0.035	0.015	0.45	0.19	0.000033	0.0014	0.0015	0.000029	0.000029	0.59	0.59	0.000056	0.000056
Uranium	1.18	0.025	0.011	[a]	[a]	0.00011	0.000033	0.025	0.011	[a]	0.000011	0.000011	0.000056	0.000056	0.023	0.023	0.00047	0.00047
TOTAL		48	20	0.21	0.089	6.9	2.9	55	23	0.0011	0.28	0.28	0.024	0.024	63	63	0.016	0.016
25th Percentile Groundwater Concentration																		
Carbon Tetrachloride	6.53	0.60	0.26	[b]	[b]	0.088	0.037	0.68	0.29	[b]	0.0036	0.0036	0.00010	0.00010	0.80	0.80	0.00020	0.00020
Chloroform	0.58	0.0037	0.0016	0.014	0.0061	0.00019	0.000078	0.018	0.0078	0.000094	0.0000081	0.00010	0.00000014	0.00000014	0.0084	0.0084	0.00000026	0.00000026
Chromium III	3.6	0.00015	0.000066	[a]	[a]	0.000026	0.0000077	0.00018	0.000073	[a]	0.0000025	0.0000025	0.000010	0.000010	0.00014	0.00014	0.000000072	0.000000072
Chromium VI (groundwater)	7	0.15	0.064	[a]	[a]	0.026	0.0078	0.18	0.072	[a]	0.0025	0.0025	0.010	0.010	0.13	0.13	0.000070	0.000070
Methylene Chloride	0.12	0.00013	0.000055	0.000045	0.000019	0.0000027	0.0000011	0.00018	0.000075	0.000000029	0.00000013	0.00000016	0.0000000017	0.0000000017	0.00057	0.00057	0.0000000032	0.0000000032
Nitrate	14,000	0.56	0.24	[b]	[b]	[b]	[b]	0.56	0.24	[b]	[b]	--	[b]	[b]	[b]	[b]	[b]	[b]
PCE	0.18	0.0012	0.00049	0.00052	0.00022	0.00038	0.00016	0.0021	0.00088	0.00000035	0.000015	0.000015	0.00000063	0.00000063	0.0013	0.0013	0.0000012	0.0000012
TCE	0.155	0.033	0.014	0.0045	0.0019	0.0032	0.0013	0.041	0.017	0.0000030	0.00013	0.00013	0.0000026	0.0000026	0.054	0.054	0.0000051	0.0000051
Uranium	0.808	0.017	0.0074	[a]	[a]	0.000075	0.000023	0.017	0.0074	[a]	0.0000073	0.0000073	0.000038	0.000038	0.015	0.015	0.00032	0.00032
TOTAL		1.4	0.6	0.019	0.0083	0.12	0.046	1.5	0.64	0.00010	0.0063	0.0064	0.010	0.010	1.0	1.0	0.00060	0.00060

Table 6-11. Summary of Non-Cancer Hazards Associated with Various Groundwater Concentrations for the Nonradionuclide COPCs Post-2150 Unrestricted Land Use–Residential Farmer. (2 sheets)

COPC	Groundwater Concentration (ug/L)	Tap Water								Irrigation			Meat		Plant		Dairy Products	
		Ingestion		Inhalation		Dermal		Total		Inhalation	Dermal	Total	Ingestion		Ingestion		Ingestion	
		Child	Adult	Child	Adult	Child	Adult	Child	Adult	Adult	Adult	Adult	Child	Adult	Child	Adult	Child	Adult
Average Groundwater Concentration																		
Carbon Tetrachloride	1,009.3	92	40	[b]	[b]	14	5.7	106	45	[b]	0.55	0.55	0.016	0.016	123	123	0.031	0.031
Chloroform	10.7	0.068	0.029	0.26	0.11	0.0034	0.0014	0.33	0.14	0.00173	0.00015	0.00188	0.0000025	0.0000025	0.15	0.15	0.000005	0.0000049
Chromium III	50.5	0.0022	0.00092	[a]	[a]	0.00036	0.00011	0.0025	0.0010	[a]	0.000035	0.000035	0.00014	0.00014	0.0019	0.0019	0.0000010	0.0000010
Chromium VI (groundwater)	74.9	1.6	0.68	[a]	[a]	0.28	0.084	1.9	0.77	[a]	0.027	0.027	0.11	0.11	1.4	1.4	0.00074	0.00074
Methylene Chloride	8.2	0.0087	0.0037	0.0030	0.00130	0.000181	0.000076	0.0119	0.0051	0.0000020	0.0000086	0.0000106	0.000000114	0.000000114	0.039	0.039	0.000000217	0.000000217
Nitrate	44,750.2	1.79	0.77	[b]	[b]	[b]	[b]	1.8	0.77	[b]	[b]	--	[b]	[b]	[b]	[b]	[b]	[b]
PCE	2.5	0.016	0.0069	0.0073	0.0031	0.0053	0.0022	0.029	0.012	0.0000049	0.00021	0.00022	0.0000088	0.0000088	0.018	0.018	0.000017	0.000017
TCE	4.7	1.0	0.43	0.14	0.059	0.10	0.041	1.25	0.53	0.000091	0.0040	0.0041	0.000080	0.000080	1.7	1.7	0.00016	0.00016
Uranium	10.1	0.22	0.093	[a]	[a]	0.00094	0.00028	0.22	0.093	[a]	0.000092	0.000092	0.00048	0.00048	0.19	0.19	0.0040	0.0040
TOTAL		97	42	0.41	0.18	14	5.9	111	48	0.0018	0.59	0.59	0.12	0.12	127	127	0.036	0.036
UCL95 Groundwater Concentration																		
Carbon Tetrachloride	1,491.3	136	58	[b]	[b]	20	8	156	67	[b]	0.82	0.82	0.023	0.023	182	182	0.046	0.046
Chloroform	19.0	0.12	0.052	0.47	0.20	0.0061	0.0026	0.60	0.26	0.00310	0.00026	0.00336	0.0000045	0.0000045	0.28	0.28	0.0000087	0.0000087
Chromium III	74.3	0.0032	0.0014	[a]	[a]	0.00053	0.00016	0.0037	0.0015	[a]	0.000052	0.000052	0.00021	0.00021	0.0028	0.0028	0.0000015	0.0000015
Chromium VI (groundwater)	176.2	3.8	1.6	[a]	[a]	0.65	0.20	4.4	1.8	[a]	0.064	0.064	0.25	0.25	3.4	3.4	0.0018	0.0018
Methylene Chloride	20.0	0.0214	0.0092	0.0074	0.00319	0.000443	0.000186	0.0292	0.0125	0.0000049	0.0000210	0.0000259	0.000000280	0.000000280	0.095	0.095	0.000000532	0.000000532
Nitrate	63,187.2	2.52	1.08	[b]	[b]	[b]	[b]	2.5	1.1	[b]	[b]	--	[b]	[b]	[b]	[b]	[b]	[b]
PCE	4.9	0.031	0.0133	0.0141	0.0061	0.0103	0.0043	0.056	0.024	0.0000093	0.00041	0.00042	0.0000169	0.0000169	0.034	0.034	0.000033	0.000033
TCE	7.2	1.5	0.65	0.21	0.089	0.15	0.061	1.88	0.81	0.00014	0.0060	0.0062	0.00012	0.00012	2.5	2.5	0.00024	0.00024
Uranium	29.5	0.63	0.27	[a]	[a]	0.00273	0.00082	0.63	0.270	[a]	0.000267	0.000267	0.00140	0.00140	0.56	0.56	0.0117	0.0117
TOTAL		145	62	0.70	0.30	21	8.7	166	71	0.0032	0.89	0.89	0.28	0.28	189	189	0.059	0.059

[a]Chemical not volatile. Inhalation from groundwater pathway incomplete for this chemical.

[b]No toxicity criteria available to quantify exposures by this pathway.

--=no value to sum

Residential Farmer Exposures to Groundwater – Radionuclides

Table 6-12. Residential Exposures to Tap Water (Radioactive Chemicals).

Ingestion of Groundwater

Future

Exposure Medium: Groundwater
Exposure Point: Drinking Water
Receptor Population: Resident
Receptor Age: Lifetime

Cancer Risk = CW x SIFc x CSF

Parameter	Unit	RME Lifetime
Chemical Conc'n in Water (CW)	pCi/L	chem-specific
Ingestion Rate of Water (IR)	L/day	2
Exposure Frequency (EF)	days/yr	350
Exposure Duration (ED)	years	30
SIFc = (IR*EF*ED)	L	2.10E+04

Chemical	CSFo (risk/pCi)
I-129 (non-dairy)	1.5E-10
Tc-99	2.75E-12
Tritium	5.07E-14

Chemical	90th Percentile CW (pCi/L)	90th Percentile Cancer Risk Lifetime
Iodine-129	1.2	3.7E-06
Tc-99	1,442	8.3E-05
Tritium	36,200	3.9E-05
TOTAL		**1.3E-04**

Table 6-13. Residential Exposures to Tap Water (Radioactive Chemicals).

Inhalation of Vapor
Future

Exposure Medium: Groundwater
Exposure Point: Drinking Water
Receptor Population: Resident
Receptor Age: Lifetime

Cancer Risk = CA x SIFc x VF x CSF

Parameter	Units	RME Lifetime
Chemical Concentration in Water (CW)	pCi/L	chem-specific
Inhalation Rate of Air (InhR)	m^3/day	20
Exposure Frequency (EF)	days/yr	350
Exposure Duration (ED)	years	30
SIFc = (InhR*EF*ED*VF)	m^3	2.1E+05

Chemical	CSFi (risk/pCi)	VF (L/m^3)
I-129 (non-dairy)	1.60E-10	--
Tc-99	--	--
Tritium	5.62E-14	0.011675

Chemical	90th Percentile CW (pCi/L)	90th Percentile Cancer Risk Lifetime
Iodine-129	1.17	--
Tc-99	1,442	--
Tritium	36,200	5.0E-06
Total		**5.0E-06**

Table 6-14. Residential Exposures to Irrigation Groundwater (Radioactive Chemicals).

Inhalation of Vapor

Future

Exposure Medium: Groundwater

Exposure Point: Irrigation Water

Receptor Population: Resident

Receptor Age: Lifetime

Cancer Risk = CA x SIFc x VF x CSF

Parameter	Units	RME Lifetime
Chemical Concentration in Water (CW)	pCi/L	chem-specific
Inhalation Rate of Air (InhR)	m^3/hour	1.5
Exposure time (ET)	hours/day	2
Exposure Frequency (EF)	days/year	90
Exposure Duration (ED)	years	30
SIFc = (InhR*ET*EF*ED*VF)	m^3	8.1E+03

Chemical	CSFi (risk/pCi)	VF (L/m^3)
I-129 (non-dairy)	1.60E-10	--
Tc-99	--	--
Tritium	5.62E-14	0.011675

Chemical	90th Percentile CW (pCi/L)	90th Percentile Cancer Risk Lifetime
Iodine-129	1.17	--
Tc-99	1,442	--
Tritium	36,200	1.9E-07
Total		**1.9E-07**

Table 6-15. Residential Exposures to Plant Tissue (Radioactive Chemicals).

Ingestion of Plant Tissue
Current/Future

Exposure Medium: Plant Tissue
Exposure Point: Plants
Receptor Population: Resident
Receptor Age: Lifetime

Cancer Risk = CTi x SIFc x CSF

Parameter	Unit	RME Lifetime
Chemical Conc'n in Tissue (CTi)	pCi/g	chem-specific
Ingestion Rate of Plant Tissue (IR)	g/day	322
Fracton of Plant from Contaminated Source (FC)	unitless	1
Exposure Frequency (EF)	days/yr	350
Exposure Duration (ED)	years	30
SIFc = (IR*FC*EF*ED)	g	3.38E+06

Chemical	CSFo (risk/pCi)
I-129 (non-dairy)	1.61E-10
Tc-99	4E-12
Tritium	1.44E-13

Chemical	90th Percentile CTi (pCi/g)	90th Percentile Cancer Risk Lifetime
Iodine-129	1.53E-02	8.3E-06
Tc-99	1.96E+02	2.6E-03
Tritium	9.50E+02	4.6E-04
Total		**3.1E-03**

Table 6-16. Residential Exposures to Livestock (Radioactive Chemicals).

Ingestion of Livestock Animal Tissue
Future

Exposure Medium: Animal Tissue
Exposure Point: Livestock
Receptor Population: Resident
Receptor Age: Lifetime

Cancer Risk = CTi x SIFc x CSF

Parameter	Unit	RME Lifetime
Chemical Conc'n in Tissue (CTi)	pCi/g	chem-specific
Ingestion Rate of Animal Tissue (IR)	g/day	169
Fracton of Tissue from Contaminated Source (FC)	unitless	1
Exposure Frequency (EF)	days/yr	350
Exposure Duration (ED)	years	30
SIFc = (IR*FC*EF*ED)	g	1.77E+06

Chemical	CSFo (risk/pCi)
I-129 (non-dairy)	1.61E-10
Tc-99	4E-12
Tritium	1.44E-13

Chemical	90th Percentile CTi (pCi/g)	90th Percentile Cancer Risk Lifetime
Iodine-129	9.82E-03	2.8E-06
Tc-99	2.43E+00	1.7E-05
Tritium	3.62E+01	9.3E-06
Total		**2.9E-05**

Table 6-17. Residential Exposures to Milk (Radioactive Chemicals).

Ingestion of Milk
Future

Exposure Medium: Milk
Exposure Point: Milk
Receptor Population: Resident
Receptor Age: Lifetime

Cancer Risk = CW x SIFc x CSF

Parameter	Unit	RME Lifetime
Chemical Conc'n in Milk (CM)	pCi/g	chem-specific
Ingestion Rate of Milk (IR)	g/day	700
Exposure Frequency (EF)	days/yr	350
Exposure Duration (ED)	years	30
SIFc = (IR*EF*ED)	g	7.35E+06

Chemical	CSFo (risk/pCi)
I-129 (dairy)	3.22E-10
Tc-99	4.0E-12
Tritium	1.44E-13

Chemical	90th Percentile CM (pCi/g)	90th Percentile Cancer Risk Lifetime
Iodine-129	0.004	1.1E-05
Tc-99	4.890	1.4E-04
Tritium	36.200	3.8E-05
Total		**1.9E-04**

Table 6-18. Summary of Cancer Risks Associated with Various Groundwater Concentrations for the Radionuclide COPCs Post-2150 Unrestricted Land Use—Residential Farmer.

COPC	Groundwater Concentration (ug/L)	Tap Water			Irrigation	Meat	Plant	Milk
		Ingestion	Inhalation	Total	Inhalation	Ingestion	Ingestion	Ingestion
90th Percentile Groundwater Concentration								
I-129	1.2	3.7E-06	[a]	3.7E-06	[a]	2.8E-06	8.3E-06	1.1E-05
Tc-99	1,442	8.3E-05	[a]	8.3E-05	[a]	1.7E-05	2.6E-03	1.4E-04
Tritium	36,200	3.9E-05	5.0E-06	4.4E-05	1.9E-07	9.3E-06	4.6E-04	3.8E-05
Total		1.3E-04	5.0E-06	1.3E-04	1.9E-07	2.9E-05	3.1E-03	1.9E-04
50th Percentile Groundwater Concentration								
I-129	0.03	9.5E-08	[a]	9.5E-08	[a]	7.2E-08	2.1E-07	2.7E-07
Tc-99	180	1.0E-05	[a]	1.0E-05	[a]	2.2E-06	3.3E-04	1.8E-05
Tritium	3,605	3.8E-06	5.0E-07	4.3E-06	1.9E-08	9.2E-07	4.6E-05	3.8E-06
Total		1.4E-05	5.0E-07	1.4E-05	1.9E-08	3.1E-06	3.6E-04	2.1E-05
25th Percentile Groundwater Concentration								
I-129	ND	[b]	[b]	[b]	[b]	[b]	[b]	[b]
Tc-99	59	3.4E-06	[a]	3.4E-06	[a]	7.1E-07	1.1E-04	5.9E-06
Tritium	513.75	5.5E-07	7.1E-08	6.2E-07	2.7E-09	1.3E-07	6.6E-06	5.4E-07
Total		3.7E-06	7.1E-08	3.7E-06	2.7E-09	7.8E-07	1.1E-04	5.9E-06
Average Groundwater Concentration								
I-129	1.3	4.1E-06	[a]	4.1E-06	[a]	3.1E-06	9.3E-06	1.2E-05
Tc-99	793	4.6E-05	[a]	4.6E-05	[a]	9.5E-06	1.5E-03	7.9E-05
Tritium	51,030	5.4E-05	7.0E-06	6.1E-05	2.7E-07	1.3E-05	6.5E-04	5.4E-05
Total		1.0E-04	7.0E-06	1.1E-04	2.7E-07	2.6E-05	2.1E-03	1.4E-04
UCL95 Groundwater Concentration								
I-129	2	7.6E-06	[a]	7.6E-06	[a]	5.8E-06	1.7E-05	2.2E-05
Tc-99	1,160	6.7E-05	[a]	6.7E-05	[a]	1.4E-05	2.1E-03	1.2E-04
Tritium	87,345	9.3E-05	1.2E-05	1.1E-04	4.6E-07	2.2E-05	1.1E-03	9.2E-05
Total		1.7E-04	1.2E-05	1.8E-04	4.6E-07	4.2E-05	3.2E-03	2.3E-04

[a]Radionuclide not volatile. Inhalation from groundwater pathway incomplete for this radionuclide.
[b]I-129 was not detected in the 25th percentile of the groundwater concentrations.

Industrial Exposures to Groundwater – Nonradionuclides

Table 6-19. Industrial Exposures (Nonradioactive Chemicals).

Ingestion of Groundwater
Future

Exposure Medium: Groundwater
Exposure Point: Drinking Water
Receptor Population: Industrial Workers
Receptor Age: Adults

Non-Cancer Hazard = CW x SIFnc / RfD
Cancer Risk = CW x SIFc x CSF

Parameter	Unit	Adult
Chemical Conc'n in Water (CW)	ug/L	chem-specific
Ingestion Rate of Water (IR)	L/day	1
Exposure frequency (EF)	days/yr	250
Exposure duration (ED)	years	25
Body weight (BW)	kg	70
Conversion Factor (CF)	mg/ug	1.00E-03
Averaging time (non-cancer) (ATnc)	days	9,125
Averaging time (cancer) (ATc)	days	25,550
SIFnc = (IR*EF*ED*CF)/(BW*ATnc)	L-mg/ug-kg-d	9.78E-06
SIFc = (IngFadj*EF*CF)/ATc	L-mg/ug-kg-d	3.49E-06

Chemical	RfDo (mg/kg-d)	CSFo $(mg/kg\text{-}d)^{-1}$
Carbon Tetrachloride	7.00E-04	1.30E-01
Chloroform	1.00E-02	--
Chromium III	1.50E+00	--
Chromium VI (groundwater)	3.00E-03	--
Methylene Chloride	6.00E-02	7.50E-03
Nitrate	1.60E+00	--
PCE	1.00E-02	5.40E-01
TCE	3.00E-04	1.30E-02
Uranium	3.00E-03	--

Total Inorganics Chemical	90th Percentile				
	CW (ug/L)	$Intake_{nc}$ adult (mg/kg-d)	$Intake_{c}$ lifetime (mg/kg-d)	HQ adult	Cancer Risk Lifetime
Carbon Tetrachloride	2,900.00	2.84E-02	1.01E-02	41	1.3E-03
Chloroform	24.00	2.35E-04	8.39E-05	0.02	--
Total Chromium	130.00	1.27E-03	4.54E-04	0.0008	--
Chromium VI	203.40	1.99E-03	7.11E-04	0.66	--
Methylene Chloride	2.73	2.68E-05	9.55E-06	0.00045	7.2E-08
Nitrate	81,050.00	7.93E-01	2.83E-01	0.50	--
PCE	2.50	2.45E-05	8.74E-06	0.0024	4.7E-06
TCE	10.90	1.07E-04	3.81E-05	0.36	5.0E-07
Uranium	8.30	8.12E-05	2.90E-05	0.027	--
Total				**42**	**1.3E-03**

Table 6-20. Industrial Exposures (Nonradioactive Chemicals).

Inhalation of Vapor
Future

Exposure Medium: Groundwater
Exposure Point: Drinking Water
Receptor Population: Industrial Worker
Receptor Age: Adults

Non-Cancer Hazard = CA x SIFnc x VFw / RfD
Cancer Risk = CA x SIFc x VFw x CSF

Parameter	Unit	Adult
Chemical Conc'n in Water (CW)	ug/L	chem-specific
Inhalation Rate (InhR)	m^3/hr	1.5
Exposure Time (ET)	hr/day	3
Exposure Frequency (EF)	days/yr	250
Exposure Duration (ED)	years	25
Body Weight (BW)	kg	70
Conversion Factor (CF)	mg/ug	1.0E-03
Averaging Time (non-cancer) (ATnc)	days	9,125
Averaging Time (cancer) (ATc)	days	25,550
SIFnc = (InhR*EF*ED*ET*CF)/(BW*ATnc)	m^3-mg/ug-kg-day	4.40E-05
SIFc = (InhR*ED*ET*EF*CF)/ATc	m^3-mg/ug-kg-day	1.57E-05

Chemical	RfDi (mg/kg-d)	CSFi $(mg/kg\text{-}d)^{-1}$	VFw[a] (L/m^3)
Carbon Tetrachloride	--	5.3E-02	5.0E-01
Chloroform	1.3E-02	8.1E-02	5.0E-01
Chromium III	--	--	--
Chromium VI (groundwater)	2.9E-05	2.9E+02	--
Methylene Chloride	8.6E-01	1.6E-03	5.0E-01
Nitrate	--	--	--
PCE	1.1E-01	2.1E-02	5.0E-01
TCE	1.1E-02	7.0E-03	5.0E-01
Uranium	--	--	--

[a]A volatilization factor (VFw) of 0.5 is only applicable for volatile chemicals.

Dissolved Inorganics Chemical	90th Percentile				
	CW (ug/L)	$Intake_{nc}$ adult (mg/kg-d)	$Intake_{c}$ lifetime (mg/kg-d)	HQ adult	Cancer Risk lifetime
Carbon Tetrachloride	2,900.00	6.38E-02	2.28E-02	--	1.2E-03
Chloroform	24.00	5.28E-04	1.89E-04	0.041	1.5E-05
Total Chromium	130.00	--	--	--	--
Chromium VI	203.40	--	--	--	--
Methylene Chloride	2.73	6.02E-05	2.15E-05	0.000070	3.4E-08
Nitrate	81,050.00	--	--	--	--
PCE	2.50	5.50E-05	1.97E-05	0.0005	4.1E-07
TCE	10.90	2.40E-04	8.57E-05	0.022	6.0E-07
Uranium	8.30	--	--	--	--
Total				**0.063**	**1.2E-03**

Table 6-21. Summary of Cancer Risks Associated with Various Groundwater Concentrations for the Nonradionuclide COPCs Post-2150 Unrestricted Land Use—Industrial Worker. (3 sheets)

COPC	Groundwater Concentration (ug/L)	Tap Water		
		Ingestion	Inhalation	Total
90th Percentile Groundwater Concentration				
Carbon Tetrachloride	2,900	1.3E-03	1.3E-03	2.6E-03
Chloroform	24	[a]	1.6E-05	1.6E-05
Chromium III	130	[a]	[a]	--
Chromium VI (groundwater)	203.4	[a]	[a]	--
Methylene Chloride	2.734	7.2E-08	3.7E-08	1.1E-07
Nitrate	81,050	[a]	[a]	--
PCE	2.5	4.7E-06	4.4E-07	5.2E-06
TCE	10.9	5.0E-07	6.0E-07	1.1E-06
Uranium	8.295	[a]	[a]	--
TOTAL		1.3E-03	1.2E-03	2.5E-03
50th Percentile Groundwater Concentration				
Carbon Tetrachloride	505	2.3E-04	2.2E-04	4.5E-04
Chloroform	6.4	[a]	4.3E-06	4.3E-06
Chromium III	10.3	[a]	[a]	--
Chromium VI (groundwater)	10.9	[a]	[a]	--
Methylene Chloride	0.185	4.8E-09	2.5E-09	7.3E-09
Nitrate	21,900	[a]	[a]	--
PCE	0.36	6.8E-07	6.3E-08	7.4E-07
TCE	1.7	7.7E-08	9.4E-08	1.7E-07
Uranium	1.18	[a]	[a]	--
TOTAL		2.3E-04	2.1E-04	4.4E-04

Table 6-21. Summary of Cancer Risks Associated with Various Groundwater Concentrations for the Nonradionuclide COPCs Post-2150 Unrestricted Land Use—Industrial Worker. (3 sheets)

COPC	Groundwater Concentration (ug/L)	Tap Water		
		Ingestion	Inhalation	Total
25th Percentile Groundwater Concentration				
Carbon Tetrachloride	6.5	3.0E-06	2.9E-06	5.9E-06
Chloroform	0.6	[a]	3.9E-07	3.9E-07
Chromium III	3.6	[a]	[a]	--
Chromium VI (groundwater)	7.0	[a]	[a]	--
Methylene Chloride	0.12	3.1E-09	1.6E-09	4.8E-09
Nitrate	14,000	[a]	[a]	--
PCE	0.18	3.4E-07	3.2E-08	3.7E-07
TCE	0.16	7.0E-09	8.5E-09	1.6E-08
Uranium	0.81	[a]	[a]	--
TOTAL		3.3E-06	3.1E-06	6.4E-06
Average Groundwater Concentration				
Carbon Tetrachloride	1,009	4.6E-04	4.5E-04	9.1E-04
Chloroform	11	[a]	7.2E-06	7.2E-06
Chromium III	50	[a]	[a]	--
Chromium VI (groundwater)	75	[a]	[a]	--
Methylene Chloride	8.2	2.1E-07	1.1E-07	3.2E-07
Nitrate	44,750	[a]	[a]	--
PCE	2.5	4.8E-06	4.5E-07	5.2E-06
TCE	4.7	2.2E-07	2.6E-07	4.8E-07
Uranium	10	[a]	[a]	--
TOTAL		4.6E-04	4.3E-04	8.9E-04

Table 6-21. Summary of Cancer Risks Associated with Various Groundwater Concentrations for the Nonradionuclide COPCs Post-2150 Unrestricted Land Use—Industrial Worker. (3 sheets)

COPC	Groundwater Concentration (ug/L)	Tap Water		
		Ingestion	Inhalation	Total
UCL95 Groundwater Concentration				
Carbon Tetrachloride	1,491	6.8E-04	6.6E-04	1.3E-03
Chloroform	19	[a]	1.3E-05	1.3E-05
Chromium III	74	[a]	[a]	--
Chromium VI (groundwater)	176	[a]	[a]	--
Methylene Chloride	20	5.3E-07	2.7E-07	7.9E-07
Nitrate	63,187	[a]	[a]	--
PCE	5	9.2E-06	8.6E-07	1.0E-05
TCE	7	3.3E-07	3.9E-07	7.2E-07
Uranium	29	[a]	[a]	--
TOTAL		6.9E-04	6.4E-04	1.3E-03

--=no value to sum

[a]Chemical not volatile. Inhalation from groundwater pathway incomplete for this chemical.

Table 6-22. Summary of Non-Cancer Hazards Associated with Various Groundwater Concentrations for the Nonradionuclide COPCs Post-2150 Unrestricted Land Use—Industrial Worker. (2 sheets)

COPC	Groundwater Concentration (ug/L)	Tap Water		
		Ingestion	Inhalation	Total
90th Percentile Groundwater Concentration				
Carbon Tetrachloride	2,900.00	41	[b]	41
Chloroform	24	0.02	0.04	0.06
Chromium III	130	0.0008	[a]	0.0008
Chromium VI (groundwater)	203.4	0.7	[a]	0.7
Methylene Chloride	2.734	0.0004	0.00007	0.0005
Nitrate	81,050	0.5	[b]	0.5
PCE	2.5	0.002	0.0005	0.003
TCE	10.9	0.4	0.02	0.4
Uranium	8.295	0.03	[a]	0.03
TOTAL		42	0.063	42
50th Percentile Groundwater Concentration				
Carbon Tetrachloride	505.00	7	[b]	7
Chloroform	6.4	0.006	0.01	0.02
Chromium III	10.3	0.00007	[a]	0.00007
Chromium VI (groundwater)	10.9	0.04	[a]	0.04
Methylene Chloride	0.185	0.00003	0.000005	0.00003
Nitrate	21,900	0.1	[b]	0.1
PCE	0.36	0.0004	0.00007	0.0004
TCE	1.7	0.06	0.003	0.06
Uranium	1.18	0.004	[a]	0.004
TOTAL		7	0.014	7
25th Percentile Groundwater Concentration				
Carbon Tetrachloride	6.5	0.09	[b]	0.1
Chloroform	0.6	0.0006	0.001	0.002
Chromium III	3.6	0.00002	[a]	0.00002
Chromium VI (groundwater)	7.0	0.02	[a]	0.02
Methylene Chloride	0.12	0.00002	0.000003	0.00002
Nitrate	14,000	0.09	[b]	0.09
PCE	0.18	0.0002	0.00004	0.0002
TCE	0.16	0.005	0.0003	0.005
Uranium	0.81	0.003	[a]	0.003
TOTAL		0.2	0.0013	0.2

Table 6-22. Summary of Non-Cancer Hazards Associated with Various Groundwater Concentrations for the Nonradionuclide COPCs Post-2150 Unrestricted Land Use—Industrial Worker. (2 sheets)

COPC	Groundwater Concentration (ug/L)	Tap Water		
		Ingestion	Inhalation	Total
Average Groundwater Concentration				
Carbon Tetrachloride	1,009	14	[b]	14
Chloroform	11	0.01	0.02	0.03
Chromium III	50	0.0003	[a]	0.0003
Chromium VI (groundwater)	75	0.2	[a]	0.2
Methylene Chloride	8.2	0.001	0.0002	0.002
Nitrate	44,750	0.3	[b]	0.3
PCE	2.5	0.002	0.0005	0.003
TCE	4.7	0.2	0.01	0.2
Uranium	10	0.03	[a]	0.03
TOTAL		15	0.028	15
UCL95 Groundwater Concentration				
Carbon Tetrachloride	1,491	21	[b]	21
Chloroform	19	0.02	0.03	0.05
Chromium III	74	0.0005	[a]	0.0005
Chromium VI (groundwater)	176	0.6	[a]	0.6
Methylene Chloride	20	0.0033	0.00051	0.0038
Nitrate	63,187	0.4	[b]	0.4
PCE	5	0.005	0.001	0.006
TCE	7	0.2	0.01	0.2
Uranium	29	0.1	[a]	0.1
TOTAL		22	0.048	22

[a]Chemical not volatile. Inhalation from groundwater pathway incomplete for this chemical.
[b]No toxicity criteria available to quantify exposures by this pathway.

Industrial Exposures to Groundwater – Radionuclides

Table 6-23. Industrial Exposures to Tap Water (Radioactive Chemicals).

Ingestion of Groundwater
Future

Exposure Medium: Groundwater
Exposure Point: Drinking Water
Receptor Population: Industrial Worker
Receptor Age: Lifetime

Cancer Risk = CW x SIFc x CSF

Parameter	Unit	RME Lifetime
Chemical Conc'n in Water (CW)	pCi/L	chem-specific
Ingestion Rate of Water (IR)	L/day	1
Exposure Frequency (EF)	days/yr	250
Exposure Duration (ED)	years	25
SIFc = (IR*EF*ED)	L	6.25E+03

Chemical	CSFo (risk/pCi)
I-129 (non-dairy)	1.5E-10
Tc-99	2.75E-12
Tritium	5.07E-14

Chemical	90th Percentile CW (pCi/L)	90th Percentile Cancer Risk Lifetime
Iodine-129	1.2	1.1E-06
Tc-99	1,442	2.5E-05
Tritium	36,200	1.1E-05
TOTAL		**3.7E-05**

Table 6-24. Industrial Exposures to Tap Water (Radioactive Chemicals).

Inhalation of Vapor
Future

Exposure Medium: Groundwater
Exposure Point: Drinking Water
Receptor Population: Industrial Worker
Receptor Age: Lifetime

Cancer Risk = CA x SIFc x VF x CSF

Parameter	Units	RME Lifetime
Chemical Concentration in Water (CW)	pCi/L	chem-specific
Inhalation Rate of Air (InhR)	m^3/hr	1.6
Exposure Time (ET)	hr/day	3
Exposure Frequency (EF)	days/yr	250
Exposure Duration (ED)	years	25
SIFc = (InhR*EF*ED*VF)	m^3	3.0E+04

Chemical	CSFi (risk/pCi)	VF (L/m^3)
I-129 (non-dairy)	1.60E-10	--
Tc-99	--	--
Tritium	5.62E-14	0.011675

Chemical	90th Percentile CW (pCi/L)	90th Percentile Cancer Risk Lifetime
Iodine-129	1.17	--
Tc-99	1,442	--
Tritium	36,200	7.1E-07
Total		**7.1E-07**

Table 6-25. Summary of Cancer Risks Associated with Various Groundwater Concentrations for the Radionuclide COPCs Post-2150 Unrestricted Land Use—Industrial Worker.

COPC	Groundwater Concentration (ug/L)	Tap Water		
		Ingestion	Inhalation	Total
90th Percentile Groundwater Concentration				
I-129	1.2	1.1E-06	[a]	1.1E-06
Tc-99	1,442	2.5E-05	[a]	2.5E-05
Tritium	36,200	1.1E-05	7.1E-07	1.2E-05
Total		3.7E-05	7.1E-07	3.8E-05
50th Percentile Groundwater Concentration				
I-129	0.03	2.8E-08	[a]	2.8E-08
Tc-99	180	3.1E-06	[a]	3.1E-06
Tritium	3,605	1.1E-06	7.1E-08	1.2E-06
Total		4.1E-06	7.1E-08	4.2E-06
25th Percentile Groundwater Concentration				
I-129	ND	[b]	[b]	[b]
Tc-99	59	1.0E-06	[a]	1.0E-06
Tritium	513.75	1.6E-07	1.0E-08	1.7E-07
Total		1.1E-06	1.0E-08	1.1E-06
Average Groundwater Concentration				
I-129	1.3	1.2E-06	[a]	1.2E-06
Tc-99	793.11	1.4E-05	[a]	1.4E-05
Tritium	51,030	1.6E-05	1.0E-06	1.7E-05
Total		3.1E-05	1.0E-06	3.2E-05
UCL95 Groundwater Concentration				
I-129	2	2.3E-06	[a]	2.3E-06
Tc-99	1,160	2.0E-05	[a]	2.0E-05
Tritium	87,345	2.8E-05	1.7E-06	2.9E-05
Total		5.0E-05	1.7E-06	5.1E-05

[a]Radionuclide not volatile. Inhalation from groundwater pathway incomplete for this radionuclide.
[b]Iodine-129 was not detected in the 25th percentile of the groundwater concentrations.

216-Z-9 Trench–Residential Exposures to Soil

Table 6-26. 216-Z-9 Trench, Residential Exposures.

Incidental Ingestion of Soil
Future

Exposure Medium: Surface Soil
Exposure Point: Residential Yard/Garden
Receptor Population: Residential Farmer
Receptor Age: Children and Adults

Non-Cancer Hazard = CS x SIFnc x ABSo / RfD
Cancer Risk = CS x SIFc x ABSo x CSF
Non-Cancer Cleanup Level = (THQ x RfD) / (SIFnc x ABSo)
Cancer Cleanup Level = (TCR) / (SIFc x CSF x ABSo)

Parameter	Units	RME Child	RME Adult
Chemical Concentration in Soil (CS)	mg/kg	chem-specific	chem-specific
Ingestion Rate of Soil (IR)	mg/day	200	100
Exposure Frequency (EF)	days/yr	350	350
Exposure Duration (ED)	years	6	24
Conversion Factor (CF)	kg/mg	1.00E-06	1.00E-06
Body Weight (BW)	kg	15	70
Averaging Time (non-cancer) (ATnc)	days	2,190	8,760
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc = (IR*EF*ED*CF)/(BW*AT)	$(day)^{-1}$	1.28E-05	1.37E-06
IngFadj (Ingestion Adjusted Factor)= (IRch*EDch/BWch)+(IRa*EDa/BWa)	mg-yr/ day-kg	114.29	
SIFc = (IngFadj*EF*CF)/ATc	$(day)^{-1}$	1.57E-06	

Chemical	RfD-O (mg/kg-d)	CSF-O $(mg/kg\text{-}d)^{-1}$	ABSo unitless
Cadmium	1.0E-03	--	1
Carbon tetrachloride	7.0E-04	1.3E-01	1
Manganese	7.0E-02	--	1

Risk Calculations–Reasonable Maximum Exposure

Chemical	CS (mg/kg)	Intake nc child (mg/kg-d)	Intake nc adult (mg/kg-d)	Intake c child/adult Lifetime (mg/kg-d)	HQ child	HQ adult	Risk child/adult Lifetime
Cadmium[a]	2.85	3.64E-05	3.90E-06	4.46E-06	0.036	0.0039	--
Carbon tetrachloride	12.67	1.62E-04	1.74E-05	1.98E-05	0.23	0.025	2.6E-06
Manganese[a]	94.05	1.20E-03	1.29E-04	1.47E-04	0.017	0.0018	--
Total					**0.29**	**0.031**	**2.6E-06**

[a]The cancer slope factor is not available for this chemical to quantify cancer risks.

Table 6-27. 216-Z-9 Trench, Residential Exposures. (2 sheets)

Dermal Contact with Soil
Future

Exposure Medium: Surface Soil
Exposure Point: Residential Yard/Garden
Receptor Population: Residential Farmer
Receptor Age: Children and Adults

Non-Cancer Hazard = CS x SIFnc x Absd / RfD
Cancer Risk = CS x SIFc x Absd x CSF

Parameter	Units	RME child	RME adult
Chemical Concentration in Soil (CS)	mg/kg	chem-specific	chem-specific
Exposure Frequency (EF)	days/yr	350	350
Exposure Duration (ED)	years	6	24
Surface Area Available for Contact (SA)	cm^2/day	2,800	5,700
Adherence Factor (AF)	mg/cm^2	0.2	0.07
Fraction of day for dermal exposures (FC)	unitless	1	1
Conversion Factor (CF)	kg/mg	1.0E-06	1.0E-06
Body Weight (BW)	kg	15	70
Averaging Time (non-cancer) (ATnc)	days	2,190	8,760
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc = (EF*ED*SA*AF*FC*CF)/(BW*ATnc)	$(day)^{-1}$	3.58E-05	5.47E-06
DFadj (Dermal Adjusted Factor) = (EDch*SAch*AFch /BWch) + (EDa*SAa*AFa/BWa)	mg-yr/day-kg	360.80	
SIFc = (DFadj*EF*FC*CF)/ATc	$(day)^{-1}$	4.94E-06	

Chemical	RfD-D (mg/kg-d)	CSF-D $(mg/kg\text{-}d)^{-1}$	AbsD
Cadmium	2.5E-05	--	1.0E-03
Carbon tetrachloride	7.0E-04	1.3E-01	--
Manganese	2.8E-03	--	--

Chemical	Risk Calculations–Reasonable Maximum Exposure						
	CS (mg/kg)	Intake nc child (mg/kg-d)	Intake nc adult (mg/kg-d)	Intake c child/adult Lifetime (mg/kg-d)	HQ child	HQ adult	Risk child/adult Lifetime
Cadmium[b]	2.85	1.02E-07	1.56E-08	1.41E-08	0.0041	0.00062	--
Carbon tetrachloride[a]	12.67	--	--	--	--	--	--
Manganese[a]	94.05	--	--	--	--	--	--
Total					**0.0041**	**0.00062**	--

[a]The absorption factor is not available for this chemical to quantify hazards or risks.
[b]The cancer slope factor is not available for this chemical to quantify cancer risks.

Table 6-28. 216-Z-9 Trench, Residential Exposures.

Inhalation of Fugitive Dust or Volatiles from Soil
Future

Exposure Medium: Surface Soil
Exposure Point: Residential Yard/Garden
Receptor Population: Residential Farmer
Receptor Age: Children and Adults

Non-Cancer Hazard = (CS x SIFnc) / (RfD x PEF(or VF))
Cancer Risk = CS x SIFc x CSF / PEF(or VF)
Non-Cancer Cleanup Level = (THQ x RfD x PEF) / (SIFnc)
Cancer Cleanup Level = (TCR x PEF) / (SIFc x CSF)

Parameter	Units	RME Adult	RME Child
Chemical Concentration in Soil (CS)	mg/kg	chem-specific	chem-specific
Inhalation Rate of Air (Inh)	m^3/day	20	10
Exposure Frequency (EF)	days/yr	350	350
Exposure Duration (ED)	years	24	6
Body Weight (BW)	kg	70	15
Averaging Time (non-cancer) (ATnc)	days	8,760	2,190
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc (child) = ((Inh-c*EF* EDc) /(BWc*ATnc-c))	m^3/kg-d	6.39E-01	
InhFadj (Inhalation Adjusted Factor)= (Inh-c*EDc/BWc) + (Inh-a*EDa/BWa)	m^3/kg-y	1.09E+01	
SIFnc (child/adult) = ((InhFadj*EF)/(ATnc))	m^3/kg-d	3.47E-01	
SIFc (child/adult) = ((InhFadj*EF)/(ATc))	m^3/kg-d	1.49E-01	

Chemical	RfD-I (mg/kg-d)	CSF-I $(mg/kg-d)^{-1}$	VF/PEF m^3/kg
Cadmium	--	6.3E+00	2.7E+09
Carbon tetrachloride	--	5.3E-02	2.2E+03
Manganese	1.4E-05	--	2.7E+09

Chemical	Risk Calculations–Reasonable Maximum Exposure CS (mg/kg)	Intake nc child (mg/kg-d)	Intake nc adult (mg/kg-d)	Intake c child/adult Lifetime (mg/kg-d)	HQ child	HQ adult	Risk child/adult Lifetime
Cadmium[a]	2.85	6.7E-10	3.6E-10	1.6E-10	--	--	9.83E-10
Carbon tetrachloride[a]	12.67	3.7E-03	2.0E-03	8.6E-04	--	--	4.54E-05
Manganese[b]	94.05	2.2E-08	1.2E-08	5.2E-09	0.0016	0.00086	--
Total					0.002	0.001	4.5E-05

[a]The reference dose is not available for this chemical to quantify hazards.
[b]The cancer slope factor is not available for this chemical to quantify cancer risks.

216-Z-9 Trench–Well Driller Exposures to Soil

Table 6-29. 216-Z-9 Trench, Well Driller Exposures.

Incidental Ingestion of Soil
Future

Exposure Medium: Soil	**Non-Cancer Hazard = CS x SIFnc x ABSo / RfD**
Receptor Population: Well Driller	**Cancer Risk = CS x SIFc x ABSo x CSF**
Receptor Age: Adults	**Non-Cancer Cleanup Level = (THQ x RfD) / (SIFnc x ABSo)**
Exposure Point: Well Tailings	**Cancer Cleanup Level = (TCR) / (SIFc x CSF x ABSo)**

Parameter	Units	RME Value
Chemical Concentration in Soil (CS)	mg/kg	chem-specific
Ingestion Rate of Soil (IR-S)	mg/day	100
Exposure Frequency (EF)	days/yr	5
Exposure Duration (ED)	years	1
Conversion Factor (CF)	kg/mg	1.0E-06
Body Weight (BW)	kg	70
Averaging Time (non-cancer) (ATnc)	days	365
Averaging Time (cancer) (ATc)	days	25,550
SIFnc = ((IR-S*EF*ED*CF)/(BW*ATnc))		1.96E-08
SIFc = ((IR-S*EF*ED*CF)/(BW*ATc))		2.80E-10
Target Hazard	unitless	1.00E+00
Target Risk	unitless	1.00E-04

Chemical	RfD-O (mg/kg-d)	CSF-O $(mg/kg\text{-}d)^{-1}$	ABSo unitless
Cadmium	1.0E-03	--	1
Carbon tetrachloride	1.0E-02	1.3E-01	1
Manganese	7.0E-02	--	1

Chemical	Risk Calculations–Reasonable Maximum Exposure				
	CS (mg/kg)	Intake nc (mg/kg-d)	Intake c (mg/kg-d)	Hazard Quotient	Cancer Risk
Cadmium[a]	8.12	1.59E-07	2.27E-09	0.00016	--
Carbon tetrachloride	36.07	7.06E-07	1.01E-08	0.000071	1.3E-09
Manganese[a]	267.78	5.24E-06	7.49E-08	0.000075	--
Total				0.00030	1.3E-09

[a]The cancer slope factor is not available for this chemical to quantify cancer risks.

Table 6-30. 216-Z-9 Trench, Well Driller Exposures.

Dermal Contact with Soil
Future

Exposure Medium: Soil
Receptor Population: Well Driller
Receptor Age: Adults
Exposure Point: Well Tailings

Non-Cancer Hazard = CS x SIFnc x Absd/ RfD
Cancer Risk = CS x SIFc x Absd x CSF
Non-Cancer Cleanup Level = (THQ x RfD) / (SIFnc x ABSd)
Cancer Cleanup Level = (TCR) / (SIFc x CSF x ABSd)

Parameter	Units	RME Value
Chemical Concentration in Soil (CS)	mg/kg	chem-specific
Adherence Factor (AF)	mg/cm^2-event	0.2
Exposure Frequency (EF)	days/yr	5
Exposure Duration (ED)	years	1
Surface Area Available for Contact (SA)	cm^2	3,300
Conversion Factor (CF)	kg/mg	1.0E-06
Dermal Absorption (AbsD)	unitless	chem-specific
Body Weight (BW)	kg	70
Averaging Time (non-cancer) (ATnc)	days	365
Averaging Time (cancer) (ATc)	days	25,550
SIFnc = ((EF*ED*SA*AF*CF)/(BW*ATnc))		1.29E-07
SIFc = ((EF*ED*SA*AF*CF)/(BW*ATc))		1.85E-09
Target Hazard	unitless	1.00E+00
Target Risk	unitless	1.00E-04

Chemical	RfD-D (mg/kg-d)	CSF-D $(mg/kg\text{-}d)^{-1}$	AbsD
Cadmium	2.5E-05	--	1.0E-03
Carbon tetrachloride	1.0E-02	1.3E-01	--
Manganese	2.8E-03	--	--

Chemical	Risk Calculations–Reasonable Maximum Exposure				
	CS (mg/kg)	Intake nc (mg/kg-d)	Intake c (mg/kg-d)	Hazard Quotient	Cancer Risk
Cadmium[b]	8.12	1.05E-09	1.50E-11	0.000042	--
Carbon tetrachloride[a]	36.07	--	--	--	--
Manganese[a]	267.78	--	--	--	--
Total				0.000042	--

[a]The absorption factor is not available for this chemical to quantify hazards or risks.
[b]The cancer slope factor is not available for this chemical to quantify cancer risks.

Table 6-31. 216-Z-9 Trench, Well Driller Exposures.

Inhalation of Fugitive Dust or Volatiles from Soil
Future

Exposure Medium: Soil
Receptor Population: Well Driller
Receptor Age: Adults
Exposure Point: Well Tailings

Non-Cancer Hazard = (CS x SIFnc) / (RfD x PEF(or VF))
Cancer Risk = CS x SIFc x CSF / PEF(or VF)
Non-Cancer Cleanup Level = (THQ x RfD x PEF) / (SIFnc)
Cancer Cleanup Level = (TCR x PEF) / (SIFc x CSF)

Parameter	Units	RME Value
Chemical Concentration in Soil (Csoil)	mg/kg	chem-specific
Inhalation Rate of Air (Inh)	m^3/day	20
Exposure Frequency (EF)	days/yr	5
Exposure Duration (ED)	years	1
Body Weight (BW)	kg	70
Averaging Time (non-cancer) (ATnc)	days	365
Averaging Time (cancer) (ATc)	days	25,550
SIFnc = ((Inh*EF*ED)/(BW*ATnc))		3.91E-03
SIFc = ((Inh*EF*ED)/(BW*ATc))		5.59E-05
Target Hazard	unitless	1.00E+00
Target Risk	unitless	1.00E-04

Chemical	RfD-I (mg/kg-d)	CSF-I $(mg/kg-d)^{-1}$	PEF/VF m^3/kg
Cadmium	--	6.3E+00	2.7E+09
Carbon tetrachloride	--	5.3E-02	5.0E+01
Manganese	1.4E-05	--	2.7E+09

Chemical	Risk Calculations–Reasonable Maximum Exposure				
	Csoil mg/kg	Intake nc (mg/kg-d)	Intake c (mg/kg-d)	Hazard Quotient	Cancer Risk
Cadmium[a]	8.12	1.2E-11	1.7E-13	--	1.1E-12
Carbon tetrachloride[a]	36.07	2.8E-03	4.0E-05	--	2.1E-06
Manganese[b]	267.78	3.9E-10	5.5E-12	0.000028	--
Total				0.000028	2.1E-06

[a]The reference dose is not available for this chemical to quantify hazards.
[b]The cancer slope factor is not available for this chemical to quantify cancer risks.

216-A-8 Crib–Residential Exposures to Soil

Table 6-32. 216-A-8 Crib, Residential Exposures. (2 sheets)

Incidental Ingestion of Soil
Future

Exposure Medium: Surface Soil
Exposure Point: Residential Yard/Garden
Receptor Population: Residential Farmer
Receptor Age: Children and Adults

Non-Cancer Hazard = CS x SIFnc x ABSo / RfD
Cancer Risk = CS x SIFc x ABSo x CSF
Non-Cancer Cleanup Level = (THQ x RfD) / (SIFnc x ABSo)
Cancer Cleanup Level = (TCR) / (SIFc x CSF x ABSo)

Parameter	Units	RME Child	RME Adult
Chemical Concentration in Soil (CS)	mg/kg	chem-specific	chem-specific
Ingestion Rate of Soil (IR)	mg/day	200	100
Exposure Frequency (EF)	days/yr	350	350
Exposure Duration (ED)	years	6	24
Conversion Factor (CF)	kg/mg	1.00E-06	1.00E-06
Body Weight (BW)	kg	15	70
Averaging Time (non-cancer) (ATnc)	days	2,190	8,760
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc = (IR*EF*ED*CF)/(BW*AT)	$(day)^{-1}$	1.28E-05	1.37E-06
IngFadj (Ingestion Adjusted Factor)= (IRch*EDch/BWch)+(IRa*EDa/BWa)	mg-yr/day-kg	114.29	
SIFc = (IngFadj*EF*CF)/ATc	$(day)^{-1}$	1.57E-06	

Chemical	RfD-O (mg/kg-d)	CSF-O $(mg/kg\text{-}d)^{-1}$	ABSo unitless
Thallium	6.6E-05	--	1

Table 6-32. 216-A-8 Crib, Residential Exposures. (2 sheets)

	Risk Calculations–Reasonable Maximum Exposure						
Chemical	CS (mg/kg)	Intake nc child (mg/kg-d)	Intake nc child/adult (mg/kg-d)	Intake c child/adult Lifetime (mg/kg-d)	HQ child	HQ child/adult	Risk child/adult Lifetime
Thallium[a]	0.19	2.43E-06	2.60E-07	2.97E-07	0.037	0.0039	--
Total					**0.037**	**0.0039**	--

[a]The cancer slope factor is not available for this chemical to quantify cancer risks.

Table 6-33. 216-A-8 Crib, Residential Exposures.

Dermal Contact with Soil
Future

Exposure Medium: Surface Soil
Exposure Point: Residential Yard/Garden
Receptor Population: Residential Farmer
Receptor Age: Children and Adults

Non-Cancer Hazard = CS x SIFnc x Absd / RfD
Cancer Risk = CS x SIFc x Absd x CSF

Parameter	Units	RME child	RME adult
Chemical Concentration in Soil (CS)	mg/kg	chem-specific	chem-specific
Exposure Frequency (EF)	days/yr	350	350
Exposure Duration (ED)	years	6	24
Surface Area Available for Contact (SA)	cm^2/day	2,800	5,700
Adherence Factor (AF)	mg/cm^2	0.2	0.07
Fraction of day for dermal exposures (FC)	unitless	1	1
Conversion Factor (CF)	kg/mg	1.0E-06	1.0E-06
Body Weight (BW)	kg	15	70
Averaging Time (non-cancer) (ATnc)	days	2,190	8,760
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc = (EF*ED*SA*AF*FC*CF)/(BW*ATnc)	$(day)^{-1}$	3.58E-05	5.47E-06
DFadj (Dermal Adjusted Factor) = (EDch*SAch*AFch /BWch) + (EDa*SAa*AFa/BWa)	mg-yr/day-kg	360.80	
SIFc = (DFadj*EF*FC*CF)/ATc	$(day)^{-1}$	4.94E-06	

Chemical	RfD-D (mg/kg-d)	CSF-D $(mg/kg-d)^{-1}$	AbsD
Thallium	6.6E-05	--	--

Chemical	Risk Calculations–Reasonable Maximum Exposure: CS (mg/kg)	Intake nc child (mg/kg-d)	Intake nc child/adult (mg/kg-d)	Intake c child/adult Lifetime (mg/kg-d)	HQ child	HQ child/adult	Risk child/adult Lifetime
Thallium[a]	0.19	--	--	--	--	--	--
Total					--	--	--

[a]The absorption factor is not available for this chemical to quantify hazards or risks.

Table 6-34: 216-A-8 Crib, Residential Exposures

Inhalation of Fugitive Dust or Volatiles from Soil
Future
Exposure Medium: Surface Soil
Exposure Point: Residential Yard/Garden
Receptor Population: Residential Farmer
Receptor Age: Children and Adults

Non-Cancer Hazard = (CS x SIFnc) / (RfD x PEF(or VF))
Cancer Risk = CS x SIFc x CSF / PEF(or VF)

Parameter	Units	RME Adult	RME Child
Chemical Concentration in Soil (CS)	mg/kg	chem-specific	chem-specific
Inhalation Rate of Air (Inh)	m^3/day	20	10
Exposure Frequency (EF)	days/yr	350	350
Exposure Duration (ED)	years	24	6
Body Weight (BW)	kg	70	15
Averaging Time (non-cancer) (ATnc)	days	8,760	2,190
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc (child) = ((Inh-c*EF* EDc) /(BWc*ATnc-c))	m^3/kg-d		6.39E-01
InhFadj (Inhalation Adjusted Factor)= (Inh-c*EDc/BWc) + (Inh-a*EDa/BWa)	m^3/kg-y	1.09E+01	
SIFnc (child/adult) = ((InhFadj*EF)/(ATnc))	m^3/kg-d	3.47E-01	
SIFc (child/adult) = ((InhFadj*EF)/(ATc))	m^3/kg-d	1.49E-01	

Chemical	RfD-I (mg/kg-d)	CSF-I $(mg/kg-d)^{-1}$	PEF m^3/kg
Thallium	--	--	2.7E+09

Risk Calculations–Reasonable Maximum Exposure

Chemical	CS (mg/kg)	Intake nc child (mg/kg-d)	Intake nc child/adult (mg/kg-d)	Intake c child/adult Lifetime (mg/kg-d)	HQ child	HQ child/adult	Risk child/adult Lifetime
Thallium[a]	0.19	4.5E-11	2.4E-11	1.0E-11	--	--	--
Total					--	--	--

[a]The reference dose and slope factor are not available for this chemical to quantify hazards and risks.

APPENDIX A

ATTACHMENT 7

SOIL RESRAD RISK SUMMARY TABLES

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216-Z-9 TRENCH SUMMARY OF RISKS

216-A-8 CRIB SUMMARY OF RISKS

216-Z-1A Tile Field – Residential

Table 7-1. Summary of Risks for the Residential Farmer from Soil—150 Years, 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	2E-14	2E-16	2E-14
Am-241	4E-05	4E-07	4E-05
Np-237	4E-09	5E-11	4E-09
Pa-231	3E-14	4E-16	3E-14
Pu-239	1E-03	1E-05	9E-04
Pu-240	2E-04	3E-06	2E-04
Ra-228	2E-18	3E-21	2E-18
Th-228	6E-19	8E-21	6E-19
Th-229	2E-15	2E-17	2E-15
Th-232	4E-19	5E-21	4E-19
U-233	2E-13	2E-15	2E-13
U-235	6E-11	6E-13	5E-11
U-236	3E-10	4E-12	3E-10
Total	1E-03	1E-05	1E-03

Table 7-2. Summary of Risks for the Residential Farmer from Soil—500 years, 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	1E-14	1E-16	1E-14
Am-241	4E-05	4E-07	4E-05
Np-237	4E-09	5E-11	4E-09
Pa-231	1E-14	2E-16	1E-14
Pu-239	6E-04	7E-06	6E-04
Pu-240	1E-04	2E-06	1E-04
Ra-228	3E-17	4E-20	3E-17
Th-228	9E-18	1E-19	9E-18
Th-229	3E-14	4E-16	3E-14
Th-232	4E-18	5E-20	4E-18
U-233	1E-14	1E-16	1E-14
U-235	9E-12	9E-14	9E-12
U-236	6E-11	6E-13	6E-11
Total	8E-04	9E-06	8E-04

Table 7-3. Summary of Risks for the Residential Farmer from Soil—1,000 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	6E-15	8E-17	6E-15
Am-241	4E-05	4E-07	4E-05
Np-237	4E-09	5E-11	4E-09
Pa-231	8E-15	1E-16	8E-15
Pu-239	4E-04	5E-06	4E-04
Pu-240	8E-05	1E-06	8E-05
Ra-228	4E-17	5E-20	4E-17
Th-228	1E-17	2E-19	1E-17
Th-229	3E-14	4E-16	3E-14
Th-232	5E-18	7E-20	5E-18
U-233	3E-16	4E-18	3E-16
U-235	6E-12	6E-14	6E-12
U-236	3E-11	4E-13	3E-11
Total	5E-04	6E-06	5E-04

Table 7-4. Summary of Risks for the Residential Farmer from Produce—150 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Produce
Ac-227	3E-13
Am-241	3E-04
Np-237	6E-07
Pa-231	2E-12
Pu-239	7E-03
Pu-240	2E-03
Ra-228	7E-16
Th-228	7E-18
Th-229	1E-14
Th-232	3E-18
U-233	4E-12
U-235	1E-09
U-236	6E-09
Total	9E-03

Table 7-5. Summary of Risks for the Residential Farmer from Produce—500 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Produce
Ac-227	2E-13
Am-241	2E-24
Np-237	9E-09
Pa-231	9E-13
Pu-239	4E-03
Pu-240	9E-04
Ra-228	9E-15
Th-228	1E-16
Th-229	2E-13
Th-232	3E-17
U-233	2E-13
U-235	2E-10
U-236	1E-09
Total	5E-03

Table 7-6. Summary of Risks for the Residential Farmer from Produce—1,000 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Produce
Ac-227	1E-13
Am-241	0E+00
Np-237	3E-10
Pa-231	6E-13
Pu-239	3E-03
Pu-240	6E-04
Ra-228	1E-14
Th-228	1E-16
Th-229	2E-13
Th-232	4E-17
U-233	6E-15
U-235	1E-10
U-236	6E-10
Total	3E-03

Table 7-7. Summary of Risks for the Residential Farmer from Radon—150 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	7E-18
Po-216	9E-20
Pb-212	3E-18
Bi-212	2E-18
Total	1E-17

Table 7-8. Summary of Risks for the Residential Farmer from Radon—500 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	1E-16
Po-216	1E-18
Pb-212	5E-17
Bi-212	3E-17
Total	2E-16

Table 7-9. Summary of Risks for the Residential Farmer from Radon—1,000 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	1E-16
Po-216	2E-18
Pb-212	8E-17
Bi-212	4E-17
Total	3E-16

Table 7-10. Summary of Risks for the Residential Farmer from External Radiation—150 years, 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	6E-12
Am-241	1E-03
Np-237	6E-06
Pa-231	3E-12
Pu-239	2E-04
Pu-240	2E-05
Ra-228	1E-15
Th-228	2E-15
Th-229	5E-13
Th-232	2E-19
U-233	4E-13
U-235	5E-08
U-236	9E-11
Total	2E-03

Table 7-11. Summary of Risks for the Residential Farmer from External Radiation—500 years, 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	4E-12
Am-241	1E-23
Np-237	1E-07
Pa-231	1E-12
Pu-239	1E-04
Pu-240	1E-05
Ra-228	2E-14
Th-228	2E-14
Th-229	8E-12
Th-232	2E-18
U-233	2E-14
U-235	9E-09
U-236	1E-11
Total	1E-04

Table 7-12. Summary of Risks for the Residential Farmer from External Radiation—1,000 years, 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	2E-12
Am-241	0E+00
Np-237	3E-09
Pa-231	9E-13
Pu-239	8E-05
Pu-240	6E-06
Ra-228	2E-14
Th-228	4E-14
Th-229	8E-12
Th-232	2E-18
U-233	6E-16
U-235	6E-09
U-236	9E-12
Total	8E-05

216-Z-1A Tile Field – Well Driller

Table 7-13. Summary of Risks for the Well Driller from Soil—150 years
216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	2E-20	5E-22	2E-20
Am-241	5E-08	9E-10	5E-08
Np-237	2E-12	4E-14	2E-12
Pa-231	8E-19	2E-20	8E-19
Pu-239	4E-07	9E-09	4E-07
Pu-240	1E-07	2E-09	1E-07
Ra-228	3E-24	7E-27	3E-24
Th-228	8E-26	2E-27	8E-26
Th-229	1E-21	2E-23	1E-21
Th-232	8E-24	2E-25	8E-24
U-233	5E-18	9E-20	4E-18
U-235	3E-14	6E-16	3E-14
U-236	2E-13	4E-15	2E-13
Total	6E-07	1E-08	6E-07

Table 7-14. Summary of Risks for the Well Driller from Soil—500 years
216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	1E-19	2E-21	1E-19
Am-241	0E+00	0E+00	0E+00
Np-237	3E-17	7E-19	3E-17
Pa-231	3E-19	7E-21	3E-19
Pu-239	1E-07	3E-09	1E-07
Pu-240	3E-08	6E-10	3E-08
Ra-228	3E-21	7E-24	3E-21
Th-228	9E-22	2E-23	9E-22
Th-229	2E-18	4E-20	2E-18
Th-232	5E-22	1E-23	5E-22
U-233	2E-21	4E-23	2E-21
U-235	7E-16	1E-17	7E-16
U-236	4E-15	8E-17	4E-15
Total	2E-07	4E-09	2E-07

Table 7-15. Summary of Risks for the Well Driller from Soil—1,000 years
216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	3E-20	6E-22	3E-20
Am-241	0E+00	0E+00	0E+00
Np-237	1E-21	2E-23	9E-22
Pa-231	8E-20	2E-21	8E-20
Pu-239	3E-08	7E-10	3E-08
Pu-240	7E-09	2E-10	7E-09
Ra-228	4E-21	8E-24	4E-21
Th-228	1E-21	2E-23	1E-21
Th-229	2E-18	3E-20	1E-18
Th-232	5E-22	1E-23	5E-22
U-233	5E-26	1E-27	5E-26
U-235	2E-16	3E-18	2E-16
U-236	1E-15	2E-17	1E-15
Total	4E-08	9E-10	4E-08

Table 7-16. Summary of Risks for the Well Driller from Radon—150 years
216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	6E-24
Po-216	8E-26
Pb-212	1E-26
Bi-212	6E-31
Total	6E-24

Table 7-17. Summary of Risks for the Well Driller from Radon—500 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	7E-20
Po-216	9E-22
Pb-212	1E-22
Bi-212	1E-26
Total	7E-20

Table 7-18. Summary of Risks for the Well Driller from Radon—1,000 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	8E-20
Po-216	1E-21
Pb-212	1E-22
Bi-212	1E-26
Total	8E-20

Table 7-19. Summary of Risks for the Well Driller from External Radiation—150 years, 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	8E-18
Am-241	2E-06
Np-237	3E-09
Pa-231	8E-17
Pu-239	9E-08
Pu-240	1E-08
Ra-228	1E-21
Th-228	2E-22
Th-229	3E-19
Th-232	5E-24
U-233	8E-18
U-235	3E-11
U-236	7E-14
Total	3E-06

Table 7-20. Summary of Risks for the Well Driller from External Radiation—500 years, 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	4E-17
Am-241	0E+00
Np-237	5E-14
Pa-231	3E-17
Pu-239	3E-08
Pu-240	3E-09
Ra-228	1E-18
Th-228	2E-18
Th-229	4E-16
Th-232	3E-22
U-233	3E-21
U-235	7E-13
U-236	1E-15
Total	3E-08

Table 7-21. Summary of Risks for the Well Driller from External Radiation—1,000 years, 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	9E-18
Am-241	0E+00
Np-237	1E-18
Pa-231	8E-18
Pu-239	7E-09
Pu-240	8E-10
Ra-228	1E-18
Th-228	2E-18
Th-229	4E-16
Th-232	3E-22
U-233	9E-26
U-235	2E-13
U-236	4E-16
Total	8E-09

216-Z-1A Tile Field – Construction Worker

Table 7-22. Summary of Risks for the Construction Worker from Soil—Now 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	3E-18	5E-19	2E-18
Am-241	3E-03	5E-04	3E-03
Np-237	4E-10	6E-11	3E-10
Pa-231	1E-16	2E-17	1E-16
Pu-239	3E-02	5E-03	2E-02
Pu-240	6E-03	1E-03	5E-03
Ra-228	3E-22	6E-24	3E-22
Th-228	7E-24	1E-24	6E-24
Th-229	1E-19	2E-20	8E-20
Th-232	1E-21	2E-22	9E-22
U-233	5E-16	8E-17	5E-16
U-235	7E-12	1E-12	6E-12
U-236	5E-11	7E-12	4E-11
Total	4E-02	6E-03	3E-02

Table 7-23. Summary of Risks for the Construction Worker from Soil—17 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	5E-14	9E-15	4E-14
Am-241	3E-03	5E-04	3E-03
Np-237	1E-08	2E-09	1E-08
Pa-231	1E-13	2E-14	9E-14
Pu-239	3E-02	5E-03	2E-02
Pu-240	6E-03	1E-03	5E-03
Ra-228	4E-18	8E-20	4E-18
Th-228	1E-18	2E-19	8E-19
Th-229	2E-15	3E-16	2E-15
Th-232	1E-18	2E-19	9E-19
U-233	5E-13	8E-14	4E-13
U-235	3E-10	4E-11	2E-10
U-236	2E-09	2E-10	1E-09
Total	4E-02	6E-03	3E-02

Table 7-24. Summary of Risks for the Construction Worker from Soil—28 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	2E-13	4E-14	2E-13
Am-241	3E-03	4E-04	3E-03
Np-237	2E-08	3E-09	2E-08
Pa-231	3E-13	5E-14	2E-13
Pu-239	3E-02	5E-03	2E-02
Pu-240	6E-03	1E-03	5E-03
Ra-228	1E-17	3E-19	1E-17
Th-228	4E-18	7E-19	3E-18
Th-229	9E-15	1E-15	7E-15
Th-232	3E-18	5E-19	2E-18
U-233	1E-12	2E-13	1E-12
U-235	4E-10	6E-11	4E-10
U-236	3E-09	4E-10	2E-09
Total	4E-02	6E-03	3E-02

Table 7-25. Summary of Risks for the Construction Worker from Soil—150 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	2E-11	3E-12	1E-11
Am-241	2E-03	3E-04	2E-03
Np-237	9E-08	2E-08	8E-08
Pa-231	8E-12	1E-12	7E-12
Pu-239	3E-02	4E-03	2E-02
Pu-240	6E-03	1E-03	5E-03
Ra-228	6E-16	1E-17	6E-16
Th-228	2E-16	4E-17	2E-16
Th-229	1E-12	2E-13	1E-12
Th-232	8E-17	1E-17	6E-17
U-233	3E-11	5E-12	3E-11
U-235	2E-09	3E-10	2E-09
U-236	1E-08	2E-09	1E-08
Total	3E-02	6E-03	3E-02

Table 7-26. Summary of Risks for the Construction Worker from Soil—500 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	2E-10	4E-11	2E-10
Am-241	1E-03	2E-04	9E-04
Np-237	2E-07	4E-08	2E-07
Pa-231	9E-11	2E-11	7E-11
Pu-239	3E-02	4E-03	2E-02
Pu-240	6E-03	1E-03	5E-03
Ra-228	7E-15	1E-16	7E-15
Th-228	2E-15	4E-16	2E-15
Th-229	4E-11	6E-12	3E-11
Th-232	8E-16	1E-16	7E-16
U-233	3E-10	4E-11	2E-10
U-235	7E-09	1E-09	6E-09
U-236	4E-08	6E-09	4E-08
Total	3E-02	6E-03	3E-02

Table 7-27. Summary of Risks for the Construction Worker from Soil—1,000 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	9E-10	1E-10	7E-10
Am-241	4E-04	6E-05	3E-04
Np-237	3E-07	5E-08	2E-07
Pa-231	3E-10	6E-11	3E-10
Pu-239	3E-02	4E-03	2E-02
Pu-240	5E-03	9E-04	4E-03
Ra-228	3E-14	5E-16	3E-14
Th-228	1E-14	2E-15	8E-15
Th-229	2E-10	4E-11	2E-10
Th-232	3E-15	5E-16	3E-15
U-233	8E-10	1E-10	7E-10
U-235	1E-08	2E-09	1E-08
U-236	8E-08	1E-08	7E-08
Total	3E-02	5E-03	3E-02

Table 7-28. Summary of Risks for the Construction Worker from Radon—Now 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	2E-23
Po-216	3E-25
Pb-212	2E-25
Bi-212	9E-29
Total	2E-23

Table 7-29. Summary of Risks for the Construction Worker from Radon—17 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	3E-18
Po-216	5E-20
Pb-212	3E-20
Bi-212	1E-23
Total	3E-18

Table 7-30. Summary of Risks for the Construction Worker from Radon—28 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	1E-17
Po-216	2E-19
Pb-212	1E-19
Bi-212	5E-23
Total	1E-17

Table 7-31. Summary of Risks for the Construction Worker from Radon—150 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	6E-16
Po-216	9E-18
Pb-212	7E-18
Bi-212	2E-21
Total	6E-16

Table 7-32. Summary of Risks for the Construction Worker from Radon—500 years 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	7E-15
Po-216	1E-16
Pb-212	8E-17
Bi-212	3E-20
Total	7E-15

Table 7-33. Summary of Risks for the Construction Worker from Radon—1,000 years, 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	3E-14
Po-216	4E-16
Pb-212	3E-16
Bi-212	1E-19
Total	3E-14

Table 7-34. Summary of Risks for the Construction Worker from External Radiation—Now, 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	1E-17
Am-241	1E-03
Np-237	6E-09
Pa-231	2E-16
Pu-239	6E-05
Pu-240	5E-06
Ra-228	2E-21
Th-228	3E-22
Th-229	3E-19
Th-232	6E-24
U-233	1E-17
U-235	9E-11
U-236	1E-13
Total	1E-03

Table 7-35. Summary of Risks for the Construction Worker from External Radiation—17 years, 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	2E-13
Am-241	1E-03
Np-237	2E-07
Pa-231	1E-13
Pu-239	6E-05
Pu-240	5E-06
Ra-228	3E-17
Th-228	4E-17
Th-229	7E-15
Th-232	6E-21
U-233	1E-14
U-235	3E-09
U-236	5E-12
Total	1E-03

Table 7-36. Summary of Risks for the Construction Worker from External Radiation—28 years, 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	1E-12
Am-241	1E-03
Np-237	4E-07
Pa-231	4E-13
Pu-239	6E-05
Pu-240	5E-06
Ra-228	1E-16
Th-228	2E-16
Th-229	3E-14
Th-232	1E-20
U-233	3E-14
U-235	5E-09
U-236	8E-12
Total	1E-03

Table 7-37. Summary of Risks for the Construction Worker from External Radiation—150 years, 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	7E-11
Am-241	1E-03
Np-237	2E-06
Pa-231	1E-11
Pu-239	6E-05
Pu-240	5E-06
Ra-228	5E-15
Th-228	8E-15
Th-229	4E-12
Th-232	4E-19
U-233	7E-13
U-235	3E-08
U-236	4E-11
Total	1E-03

Table 7-38. Summary of Risks for the Construction Worker from External Radiation—500 years, 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	1E-09
Am-241	5E-04
Np-237	4E-06
Pa-231	1E-10
Pu-239	6E-05
Pu-240	5E-06
Ra-228	5E-14
Th-228	9E-14
Th-229	1E-10
Th-232	4E-18
U-233	6E-12
U-235	8E-08
U-236	1E-10
Total	6E-04

Table 7-39. Summary of Risks for the Construction Worker from External Radiation—1,000 years, 216-Z-1A Tile Field.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	4E-09
Am-241	2E-04
Np-237	5E-06
Pa-231	4E-10
Pu-239	6E-05
Pu-240	5E-06
Ra-228	2E-13
Th-228	4E-13
Th-229	7E-10
Th-232	2E-17
U-233	2E-11
U-235	2E-07
U-236	2E-10
Total	2E-04

216-Z-8 French Drain – Residential

Table 7-40. Summary of Risks for the Residential Farmer from Soil—150 years
216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	1E-18	2E-20	1E-18
Am-241	2E-08	3E-10	2E-08
Np-237	3E-12	3E-14	3E-12
Pa-231	3E-18	4E-20	3E-18
Pb-210	8E-18	3E-21	8E-18
Pu-238	7E-09	9E-11	7E-09
Pu-239	1E-06	2E-08	1E-06
Pu-240	3E-07	4E-09	3E-07
Ra-226	7E-18	1E-20	7E-18
Ra-228	2E-22	2E-25	2E-22
Th-228	4E-23	6E-25	4E-23
Th-229	1E-18	1E-20	1E-18
Th-230	4E-16	4E-18	4E-16
Th-232	4E-23	5E-25	4E-23
U-233	1E-16	2E-18	1E-16
U-234	2E-12	2E-14	2E-12
U-235	8E-15	8E-17	8E-15
U-236	5E-14	5E-16	5E-14
Total	2E-06	2E-08	2E-06

Table 7-41. Summary of Risks for the Residential Farmer from Soil—500 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	1E-17	2E-19	1E-17
Am-241	3E-28	0E+00	3E-28
Np-237	9E-14	1E-15	9E-14
Pa-231	2E-17	2E-19	2E-17
Pb-210	4E-16	1E-19	4E-16
Pu-238	9E-11	1E-12	9E-11
Pu-239	8E-07	1E-08	8E-07
Pu-240	2E-07	2E-09	2E-07
Ra-226	1E-16	2E-19	1E-16
Ra-228	3E-20	4E-23	3E-20
Th-228	9E-21	1E-22	9E-21
Th-229	4E-17	5E-19	4E-17
Th-230	1E-15	2E-17	1E-15
Th-232	4E-21	4E-23	3E-21
U-233	1E-17	2E-19	1E-17
U-234	5E-15	6E-17	5E-15
U-235	1E-14	1E-16	1E-14
U-236	8E-14	9E-16	8E-14
Total	1E-06	1E-08	1E-06

Table 7-42. Summary of Risks for the Residential Farmer from Soil—1,000 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	9E-18	1E-19	9E-18
Am-241	0E+00	0E+00	0E+00
Np-237	3E-15	3E-17	3E-15
Pa-231	1E-17	1E-19	1E-17
Pb-210	4E-16	1E-19	4E-16
Pu-238	1E-12	1E-14	1E-12
Pu-239	5E-07	6E-09	5E-07
Pu-240	1E-07	1E-09	1E-07
Ra-226	1E-16	2E-19	1E-16
Ra-228	5E-20	6E-23	5E-20
Th-228	1E-20	2E-22	1E-20
Th-229	4E-17	5E-19	4E-17
Th-230	1E-15	2E-17	1E-15
Th-232	6E-21	7E-23	6E-21
U-233	4E-19	5E-21	4E-19
U-234	6E-17	7E-19	6E-17
U-235	8E-15	8E-17	8E-15
U-236	5E-14	5E-16	5E-14
Total	6E-07	8E-09	6E-07

Table 7-43. Summary of Risks for the Residential Farmer from Produce—150 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Produce
Ac-227	2E-17
Am-241	2E-07
Np-237	4E-10
Pa-231	2E-16
Pb-210	6E-16
Pu-238	5E-08
Pu-239	9E-06
Pu-240	2E-06
Ra-226	2E-15
Ra-228	5E-20
Th-228	5E-22
Th-229	8E-18
Th-230	3E-15
Th-232	3E-22
U-233	3E-15
U-234	4E-11
U-235	1E-13
U-236	9E-13
Total	1E-05

Table 7-44. Summary of Risks for the Residential Farmer from Produce—500 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Produce
Ac-227	2E-16
Am-241	2E-27
Np-237	1E-11
Pa-231	1E-15
Pb-210	3E-14
Pu-238	6E-10
Pu-239	6E-06
Pu-240	1E-06
Ra-226	3E-14
Ra-228	9E-18
Th-228	1E-19
Th-229	3E-16
Th-230	1E-14
Th-232	2E-20
U-233	2E-16
U-234	9E-14
U-235	2E-13
U-236	1E-12
Total	7E-06

Table 7-45. Summary of Risks for the Residential Farmer from Produce—1,000 years, 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Produce
Ac-227	2E-16
Am-241	0E+00
Np-237	4E-13
Pa-231	8E-16
Pb-210	3E-14
Pu-238	8E-12
Pu-239	4E-06
Pu-240	8E-07
Ra-226	3E-14
Ra-228	1E-17
Th-228	2E-19
Th-229	3E-16
Th-230	1E-14
Th-232	4E-20
U-233	8E-18
U-234	1E-15
U-235	1E-13
U-236	8E-13
Total	4E-06

Table 7-46. Summary of Risks for the Residential Farmer from Radon—150 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	9E-15
Po-218	2E-14
Pb-214	2E-14
Bi-214	5E-14
Rn-220	5E-22
Po-216	7E-24
Pb-212	2E-22
Bi-212	1E-22
Total	1E-13

Table 7-47. Summary of Risks for the Residential Farmer from Radon—500 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	1E-13
Po-218	3E-13
Pb-214	4E-13
Bi-214	7E-13
Rn-220	1E-19
Po-216	1E-21
Pb-212	5E-20
Bi-212	3E-20
Total	1E-12

Table 7-48. Summary of Risks for the Residential Farmer from Radon—1,000 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	1E-13
Po-218	3E-13
Pb-214	4E-13
Bi-214	7E-13
Rn-220	2E-19
Po-216	2E-21
Pb-212	8E-20
Bi-212	5E-20
Total	1E-12

Table 7-49. Summary of Risks for the Residential Farmer from External Radiation—150 years, 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	7E-15
Am-241	1E-12
Np-237	2E-09
Pa-231	3E-15
Pb-210	7E-17
Pu-238	2E-10
Pu-239	2E-07
Pu-240	2E-08
Ra-226	2E-13
Ra-228	5E-18
Th-228	8E-18
Th-229	7E-15
Th-230	2E-15
Th-232	5E-22
U-233	3E-16
U-234	6E-14
U-235	2E-11
U-236	3E-14
Total	3E-07

Table 7-50. Summary of Risks for the Residential Farmer from External Radiation—500 years, 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	5E-15
Am-241	1E-26
Np-237	1E-10
Pa-231	2E-15
Pb-210	9E-17
Pu-238	7E-12
Pu-239	2E-07
Pu-240	1E-08
Ra-226	3E-13
Ra-228	2E-17
Th-228	2E-17
Th-229	1E-14
Th-230	2E-15
Th-232	2E-21
U-233	3E-17
U-234	2E-15
U-235	1E-11
U-236	2E-14
Total	2E-07

Table 7-51. Summary of Risks for the Residential Farmer from External Radiation—1,000 years, 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	3E-15
Am-241	0E+00
Np-237	4E-12
Pa-231	1E-15
Pb-210	9E-17
Pu-238	9E-14
Pu-239	1E-07
Pu-240	8E-09
Ra-226	3E-13
Ra-228	2E-17
Th-228	4E-17
Th-229	1E-14
Th-230	2E-15
Th-232	3E-21
U-233	8E-19
U-234	3E-17
U-235	8E-12
U-236	1E-14
Total	1E-07

216-Z-8 French Drain – Well Driller

Table 7-52. Summary of Risks for the Well Driller from Soil—150 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	6E-26	1E-27	6E-26
Am-241	3E-11	5E-13	3E-11
Np-237	1E-15	3E-17	1E-15
Pa-231	3E-24	6E-26	3E-24
Pb-210	3E-25	2E-28	3E-25
Pu-238	4E-12	8E-14	4E-12
Pu-239	6E-10	1E-11	6E-10
Pu-240	1E-10	3E-12	1E-10
Ra-226	5E-24	2E-26	5E-24
Ra-228	8E-30	0E+00	8E-30
Th-228	0E+00	0E+00	0E+00
Th-229	8E-25	2E-26	8E-25
Th-230	8E-21	2E-22	8E-21
Th-232	2E-29	3E-31	2E-29
U-233	3E-21	7E-23	3E-21
U-234	1E-15	3E-17	1E-15
U-235	2E-19	3E-21	2E-19
U-236	1E-18	2E-20	1E-18
Total	8E-10	2E-11	8E-10

Table 7-53. Summary of Risks for the Well Driller from Soil—500 years
216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	1E-22	3E-24	1E-22
Am-241	0E+00	0E+00	0E+00
Np-237	5E-20	1E-21	5E-20
Pa-231	5E-22	1E-23	5E-22
Pb-210	2E-20	1E-23	2E-20
Pu-238	2E-14	5E-16	2E-14
Pu-239	2E-10	4E-12	2E-10
Pu-240	4E-11	9E-13	4E-11
Ra-226	6E-21	2E-23	6E-21
Ra-228	3E-24	6E-27	3E-24
Th-228	9E-25	2E-26	9E-25
Th-229	2E-21	5E-23	2E-21
Th-230	3E-19	5E-21	3E-19
Th-232	5E-25	1E-26	5E-25
U-233	3E-24	5E-26	3E-24
U-234	4E-19	8E-21	4E-19
U-235	1E-18	2E-20	1E-18
U-236	6E-18	1E-19	6E-18
Total	2E-10	5E-12	2E-10

Table 7-54. Summary of Risks for the Well Driller from Soil—1,000 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	4E-23	8E-25	4E-23
Am-241	0E+00	0E+00	0E+00
Np-237	1E-24	3E-26	1E-24
Pa-231	1E-22	3E-24	1E-22
Pb-210	1E-20	9E-24	1E-20
Pu-238	1E-16	2E-18	1E-16
Pu-239	5E-11	1E-12	5E-11
Pu-240	1E-11	2E-13	1E-11
Ra-226	6E-21	2E-23	6E-21
Ra-228	4E-24	8E-27	4E-24
Th-228	1E-24	3E-26	1E-24
Th-229	2E-21	5E-23	2E-21
Th-230	3E-19	5E-21	2E-19
Th-232	6E-25	1E-26	5E-25
U-233	7E-29	1E-30	7E-29
U-234	2E-21	4E-23	2E-21
U-235	3E-19	5E-21	3E-19
U-236	2E-18	3E-20	1E-18
Total	6E-11	1E-12	6E-11

Table 7-55. Summary of Risks for the Well Driller from Radon—150 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	3E-24
Po-218	2E-26
Pb-214	5E-30
Rn-220	1E-29
Total	3E-24

Table 7-56. Summary of Risks for the Well Driller from Radon—500 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	4E-21
Po-218	2E-23
Pb-214	6E-27
Rn-220	7E-23
Po-216	9E-25
Pb-212	1E-25
Bi-212	9E-30
Total	4E-21

Table 7-57. Summary of Risks for the Well Driller from Radon—1,000 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	4E-21
Po-218	2E-23
Pb-214	6E-27
Rn-220	8E-23
Po-216	1E-24
Pb-212	1E-25
Bi-212	1E-29
Total	4E-21

Table 7-58. Summary of Risks for the Well Driller from External Radiation—150 years, 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	2E-23
Am-241	2E-09
Np-237	2E-12
Pa-231	3E-22
Pb-210	7E-26
Pu-238	5E-13
Pu-239	1E-10
Pu-240	2E-11
Ra-226	1E-20
Ra-228	3E-27
Th-228	3E-28
Th-229	2E-22
Th-230	1E-20
Th-232	1E-29
U-233	6E-21
U-234	9E-16
U-235	2E-16
U-236	3E-19
Total	2.E-09

Table 7-59. Summary of Risks for the Well Driller from External Radiation—500 years, 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	5E-20
Am-241	0E+00
Np-237	7E-17
Pa-231	5E-20
Pb-210	4E-21
Pu-238	3E-15
Pu-239	4E-11
Pu-240	5E-12
Ra-226	1E-17
Ra-228	1E-21
Th-228	2E-21
Th-229	6E-19
Th-230	4E-19
Th-232	3E-25
U-233	5E-24
U-234	2E-19
U-235	1E-15
U-236	2E-18
Total	5.E-11

Table 7-60. Summary of Risks for the Well Driller from External Radiation—1,000 years, 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	1E-20
Am-241	0E+00
Np-237	2E-21
Pa-231	1E-20
Pb-210	4E-21
Pu-238	1E-17
Pu-239	1E-11
Pu-240	1E-12
Ra-226	1E-17
Ra-228	1E-21
Th-228	2E-21
Th-229	5E-19
Th-230	4E-19
Th-232	3E-25
U-233	1E-28
U-234	1E-21
U-235	3E-16
U-236	5E-19
Total	1.E-11

216-Z-8 French Drain – Construction Worker

Table 7-61. Summary of Risks for the Construction Worker from Soil—Now 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	7E-23	7E-23	2E-24
Am-241	5E-08	5E-08	1E-09
Np-237	7E-15	7E-15	2E-16
Pa-231	3E-21	3E-21	7E-23
Pb-210	4E-26	2E-26	2E-26
Pu-238	1E-08	1E-08	3E-10
Pu-239	7E-07	6E-07	2E-08
Pu-240	1E-07	1E-07	3E-09
Ra-226	4E-24	3E-24	4E-25
Ra-228	1E-27	8E-28	2E-28
Th-228	2E-28	2E-28	4E-30
Th-229	2E-24	2E-24	4E-26
Th-230	4E-20	3E-20	9E-22
Th-232	3E-26	3E-26	6E-28
U-233	1E-20	9E-21	2E-22
U-234	1E-14	9E-15	2E-16
U-235	1E-16	1E-16	4E-18
U-236	1E-15	1E-15	3E-17
Total	9E-07	8E-07	2E-08

Table 7-62. Summary of Risks for the Construction Worker from Soil—17 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	1E-18	1E-18	3E-20
Am-241	5E-08	5E-08	1E-09
Np-237	2E-13	2E-13	5E-15
Pa-231	3E-18	3E-18	6E-20
Pb-210	2E-20	9E-21	7E-21
Pu-238	1E-08	1E-08	3E-10
Pu-239	7E-07	6E-07	2E-08
Pu-240	1E-07	1E-07	3E-09
Ra-226	7E-20	6E-20	9E-21
Ra-228	1E-23	1E-23	3E-24
Th-228	3E-23	3E-23	6E-25
Th-229	4E-20	4E-20	9E-22
Th-230	3E-17	3E-17	8E-19
Th-232	3E-23	3E-23	6E-25
U-233	9E-18	8E-18	2E-19
U-234	3E-13	3E-13	8E-15
U-235	5E-15	5E-15	1E-16
U-236	4E-14	3E-14	9E-16
Total	9E-07	8E-07	2E-08

Table 7-63. Summary of Risks for the Construction Worker from Soil—28 years
216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	5E-18	5E-18	1E-19
Am-241	5E-08	5E-08	1E-09
Np-237	4E-13	4E-13	8E-15
Pa-231	7E-18	7E-18	2E-19
Pb-210	1E-19	6E-20	5E-20
Pu-238	1E-08	1E-08	2E-10
Pu-239	7E-07	6E-07	2E-08
Pu-240	1E-07	1E-07	3E-09
Ra-226	3E-19	3E-19	4E-20
Ra-228	5E-23	4E-23	1E-23
Th-228	1E-22	1E-22	2E-24
Th-229	2E-19	2E-19	4E-21
Th-230	8E-17	8E-17	2E-18
Th-232	7E-23	7E-23	2E-24
U-233	2E-17	2E-17	6E-19
U-234	5E-13	5E-13	1E-14
U-235	8E-15	8E-15	2E-16
U-236	6E-14	6E-14	1E-15
Total	9E-07	8E-07	2E-08

Table 7-64. Summary of Risks for the Construction Worker from Soil—150 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	3E-16	3E-16	8E-18
Am-241	3E-08	3E-08	8E-10
Np-237	1E-12	1E-12	3E-14
Pa-231	2E-16	2E-16	4E-18
Pb-210	4E-17	2E-17	2E-17
Pu-238	4E-09	4E-09	9E-11
Pu-239	6E-07	6E-07	1E-08
Pu-240	1E-07	1E-07	3E-09
Ra-226	3E-17	3E-17	4E-18
Ra-228	2E-21	2E-21	4E-22
Th-228	5E-21	5E-21	1E-22
Th-229	2E-17	2E-17	5E-19
Th-230	2E-15	2E-15	4E-17
Th-232	2E-21	2E-21	4E-23
U-233	5E-16	5E-16	1E-17
U-234	2E-12	2E-12	4E-14
U-235	4E-14	4E-14	1E-15
U-236	3E-13	3E-13	7E-15
Total	8E-07	8E-07	2E-08

Table 7-65. Summary of Risks for the Construction Worker from Soil—500 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	4E-15	4E-15	9E-17
Am-241	8E-09	7E-09	2E-10
Np-237	3E-12	3E-12	6E-14
Pa-231	2E-15	2E-15	4E-17
Pb-210	9E-16	5E-16	4E-16
Pu-238	2E-10	2E-10	6E-12
Pu-239	6E-07	6E-07	1E-08
Pu-240	1E-07	1E-07	3E-09
Ra-226	6E-16	5E-16	7E-17
Ra-228	2E-20	2E-20	4E-21
Th-228	6E-20	6E-20	1E-21
Th-229	5E-16	5E-16	1E-17
Th-230	8E-15	8E-15	2E-16
Th-232	2E-20	2E-20	4E-22
U-233	3E-15	3E-15	8E-17
U-234	2E-12	2E-12	4E-14
U-235	1E-13	1E-13	3E-15
U-236	8E-13	8E-13	2E-14
Total	8E-07	8E-07	2E-08

Table 7-66. Summary of Risks for the Construction Worker from Soil—1,000 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	1E-14	1E-14	3E-16
Am-241	1E-09	1E-09	3E-11
Np-237	3E-12	3E-12	7E-14
Pa-231	5E-15	5E-15	1E-16
Pb-210	4E-15	2E-15	2E-15
Pu-238	5E-12	4E-12	1E-13
Pu-239	6E-07	6E-07	1E-08
Pu-240	1E-07	1E-07	3E-09
Ra-226	2E-15	2E-15	3E-16
Ra-228	7E-20	6E-20	1E-20
Th-228	2E-19	2E-19	4E-21
Th-229	2E-15	2E-15	6E-17
Th-230	2E-14	2E-14	4E-16
Th-232	6E-20	6E-20	1E-21
U-233	7E-15	7E-15	2E-16
U-234	1E-12	1E-12	3E-14
U-235	2E-13	2E-13	5E-15
U-236	1E-12	1E-12	3E-14
Total	8E-07	7E-07	2E-08

Table 7-67. Summary of Risks for the Construction Worker from Radon—Now 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	9E-26
Po-218	8E-29
Pb-214	0E+00
Rn-220	5E-30
Po-216	0E+00
Pb-212	0E+00
Total	9E-26

Table 7-68. Summary of Risks for the Construction Worker from Radon—17 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	2E-21
Po-218	2E-24
Pb-214	7E-29
Rn-220	8E-25
Po-216	4E-27
Pb-212	8E-29
Total	2E-21

Table 7-69. Summary of Risks for the Construction Worker from Radon—28 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	8E-21
Po-218	7E-24
Pb-214	3E-28
Rn-220	3E-24
Po-216	2E-26
Pb-212	3E-28
Total	8E-21

Table 7-70. Summary of Risks for the Construction Worker from Radon—150 years 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	9E-19
Po-218	8E-22
Pb-214	3E-26
Rn-220	2E-22
Po-216	9E-25
Pb-212	2E-26
Total	9E-19

Table 7-71. Summary of Risks for the Construction Worker from Radon —500 years, 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	2E-17
Po-218	1E-20
Pb-214	6E-25
Rn-220	2E-21
Po-216	1E-23
Pb-212	2E-25
Total	2E-17

Table 7-72. Summary of Risks for the Construction Worker from Radon —1,000 years, 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	6E-17
Po-218	5E-20
Pb-214	2E-24
Rn-220	6E-21
Po-216	3E-23
Pb-212	6E-25
Total	6E-17

Table 7-73. Summary of Risks for the Construction Worker from External Radiation—Now, 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	8E-22
Am-241	7E-08
Np-237	3E-13
Pa-231	1E-20
Pb-210	5E-27
Pu-238	4E-11
Pu-239	4E-09
Pu-240	4E-10
Ra-226	2E-21
Ra-228	1E-25
Th-228	2E-26
Th-229	2E-23
Th-230	2E-21
Th-232	4E-28
U-233	6E-22
U-234	2E-16
U-235	6E-15
U-236	1E-17
Total	8E-08

Table 7-74. Summary of Risks for the Construction Worker from External Radiation—17 years, 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	2E-17
Am-241	7E-08
Np-237	1E-11
Pa-231	9E-18
Pb-210	2E-21
Pu-238	3E-11
Pu-239	4E-09
Pu-240	4E-10
Ra-226	3E-17
Ra-228	2E-21
Th-228	2E-21
Th-229	3E-19
Th-230	1E-18
Th-232	4E-25
U-233	5E-19
U-234	5E-15
U-235	2E-13
U-236	3E-16
Total	7E-08

Table 7-75. Summary of Risks for the Construction Worker from External Radiation—28 years, 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	6E-17
Am-241	7E-08
Np-237	2E-11
Pa-231	2E-17
Pb-210	1E-20
Pu-238	3E-11
Pu-239	4E-09
Pu-240	4E-10
Ra-226	1E-16
Ra-228	7E-21
Th-228	9E-21
Th-229	1E-18
Th-230	3E-18
Th-232	1E-24
U-233	1E-18
U-234	8E-15
U-235	3E-13
U-236	6E-16
Total	7E-08

Table 7-76. Summary of Risks for the Construction Worker from External Radiation—150 years, 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	4E-15
Am-241	4E-08
Np-237	7E-11
Pa-231	6E-16
Pb-210	5E-18
Pu-238	1E-11
Pu-239	4E-09
Pu-240	4E-10
Ra-226	1E-14
Ra-228	3E-19
Th-228	4E-19
Th-229	2E-16
Th-230	7E-17
Th-232	3E-23
U-233	3E-17
U-234	3E-14
U-235	2E-12
U-236	3E-15
Total	5E-08

Table 7-77. Summary of Risks for the Construction Worker from External Radiation—500 years, 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	5E-14
Am-241	1E-08
Np-237	1E-10
Pa-231	5E-15
Pb-210	1E-16
Pu-238	8E-13
Pu-239	4E-09
Pu-240	4E-10
Ra-226	3E-13
Ra-228	3E-18
Th-228	5E-18
Th-229	4E-15
Th-230	4E-16
Th-232	3E-22
U-233	2E-16
U-234	3E-14
U-235	4E-12
U-236	8E-15
Total	2E-08

Table 7-78. Summary of Risks for the Construction Worker from External Radiation—1,000 years, 216-Z-8 French Drain.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	1E-13
Am-241	1E-09
Np-237	1E-10
Pa-231	2E-14
Pb-210	5E-16
Pu-238	1E-14
Pu-239	4E-09
Pu-240	4E-10
Ra-226	1E-12
Ra-228	1E-17
Th-228	2E-17
Th-229	2E-14
Th-230	7E-16
Th-232	9E-22
U-233	4E-16
U-234	2E-14
U-235	7E-12
U-236	1E-14
Total	6E-09

216-Z-9 Trench – Residential

Table 7-79. Summary of Risks for the Residential Farmer from Soil—150 years 216-Z-9 Trench.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	3E-08	4E-10	3E-08
Am-241	1E-04	1E-06	1E-04
Eu-152	1E-12	1E-15	1E-12
Gd-152	2E-25	2E-27	2E-25
Ni-63	7E-09	2E-12	7E-09
Np-237	1E-07	1E-09	1E-07
Pa-231	2E-08	2E-10	2E-08
Pb-210	5E-07	2E-10	5E-07
Pu-238	1E-06	2E-08	1E-06
Pu-239	1E-02	2E-04	1E-02
Pu-240	3E-03	4E-05	3E-03
Ra-226	6E-08	1E-10	6E-08
Ra-228	8E-16	1E-18	8E-16
Sr-90	1E-10	3E-14	1E-10
Tc-99	3E-19	1E-22	3E-19
Th-228	4E-16	5E-18	4E-16
Th-229	5E-13	7E-15	5E-13
Th-230	2E-08	3E-10	2E-08
Th-232	6E-18	7E-20	6E-18
U-233	4E-11	5E-13	4E-11
U-234	5E-10	5E-12	5E-10
U-235	8E-10	8E-12	8E-10
U-236	5E-09	5E-11	5E-09
Total	2E-02	2E-04	2E-02

Table 7-80. Summary of Risks for the Residential Farmer from Soil—500 years 216-Z-9 Trench.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	1E-13	2E-15	1E-13
Am-241	3E-24	4E-26	3E-24
Eu-152	2E-24	2E-27	2E-24
Gd-152	1E-25	1E-27	1E-25
Ni-63	8E-11	2E-14	8E-11
Np-237	3E-09	4E-11	3E-09
Pa-231	2E-13	2E-15	2E-13
Pb-210	7E-09	3E-12	7E-09
Pu-238	2E-08	2E-10	2E-08
Pu-239	8E-03	1E-04	8E-03
Pu-240	2E-03	2E-05	2E-03
Ra-226	2E-09	4E-12	2E-09
Ra-228	4E-16	5E-19	4E-16
Sr-90	9E-29	0E+00	9E-29
Tc-99	0E+00	0E+00	0E+00
Th-228	1E-16	2E-18	1E-16
Th-229	3E-12	3E-14	2E-12
Th-230	2E-08	3E-10	2E-08
Th-232	5E-17	6E-19	5E-17
U-233	5E-13	6E-15	5E-13
U-234	1E-12	1E-14	1E-12
U-235	1E-10	1E-12	1E-10
U-236	8E-10	8E-12	7E-10
Total	1E-02	1E-04	1E-02

Table 7-81. Summary of Risks for the Residential Farmer from Soil—1,000 years, 216-Z-9 Trench.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	9E-14	1E-15	9E-14
Am-241	0E+00	0E+00	0E+00
Eu-152	0E+00	0E+00	0E+00
Gd-152	5E-26	4E-28	5E-26
Ni-63	8E-13	2E-16	8E-13
Np-237	9E-11	1E-12	9E-11
Pa-231	1E-13	2E-15	1E-13
Pb-210	7E-09	2E-12	7E-09
Pu-238	2E-10	3E-12	2E-10
Pu-239	5E-03	6E-05	5E-03
Pu-240	1E-03	1E-05	1E-03
Ra-226	2E-09	4E-12	2E-09
Ra-228	6E-16	7E-19	6E-16
Sr-90	0E+00	0E+00	0E+00
Tc-99	0E+00	0E+00	0E+00
Th-228	2E-16	2E-18	2E-16
Th-229	2E-12	3E-14	2E-12
Th-230	2E-08	3E-10	2E-08
Th-232	7E-17	9E-19	7E-17
U-233	1E-14	2E-16	1E-14
U-234	1E-14	1E-16	1E-14
U-235	8E-11	8E-13	8E-11
U-236	5E-10	5E-12	5E-10
Total	6E-03	8E-05	6E-03

Table 7-82. Summary of Risks for the Residential Farmer from Produce—150 years 216-Z-9 Trench.

Radionuclide (Parent and Decay)	Produce
Ac-227	6E-07
Am-241	8E-04
Eu-152	3E-11
Gd-152	4E-24
Ni-63	2E-06
Np-237	1E-05
Pa-231	1E-06
Pb-210	3E-05
Pu-238	1E-05
Pu-239	9E-02
Pu-240	2E-02
Ra-226	2E-05
Ra-228	2E-13
Sr-90	3E-07
Tc-99	1E-14
Th-228	3E-15
Th-229	4E-12
Th-230	2E-07
Th-232	4E-17
U-233	8E-10
U-234	8E-09
U-235	1E-08
U-236	8E-08
Total	1E-01

Table 7-83. Summary of Risks for the Residential Farmer from Produce—500 years 216-Z-9 Trench.

Radionuclide (Parent and Decay)	Produce
Ac-227	2E-12
Am-241	2E-23
Eu-152	4E-23
Gd-152	3E-24
Ni-63	3E-08
Np-237	4E-07
Pa-231	1E-11
Pb-210	5E-07
Pu-238	1E-07
Pu-239	6E-02
Pu-240	1E-02
Ra-226	5E-07
Ra-228	1E-13
Sr-90	2E-25
Tc-99	0E+00
Th-228	1E-15
Th-229	2E-11
Th-230	2E-07
Th-232	3E-16
U-233	9E-12
U-234	2E-11
U-235	2E-09
U-236	1E-08
Total	7E-02

Table 7-84. Summary of Risks for the Residential Farmer from Produce—
1,000 years, 216-Z-9 Trench.

Radionuclide (Parent and Decay)	**Produce**
Ac-227	2E-12
Am-241	0E+00
Eu-152	0E+00
Gd-152	8E-25
Ni-63	3E-10
Np-237	1E-08
Pa-231	8E-12
Pb-210	5E-07
Pu-238	1E-09
Pu-239	4E-02
Pu-240	7E-03
Ra-226	5E-07
Ra-228	2E-13
Sr-90	0E+00
Tc-99	0E+00
Th-228	2E-15
Th-229	2E-11
Th-230	2E-07
Th-232	5E-16
U-233	3E-13
U-234	2E-13
U-235	1E-09
U-236	8E-09
Total	4E-02

Table 7-85. Summary of Risks for the Residential Farmer from Radon—150 years 216-Z-9 Trench.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	9E-05
Po-218	2E-04
Pb-214	2E-04
Bi-214	4E-04
Rn-220	4E-15
Po-216	6E-17
Pb-212	2E-15
Bi-212	1E-15
Total	9E-04

Table 7-86. Summary of Risks for the Residential Farmer from Radon–500 years 216-Z-9 Trench.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	2E-06
Po-218	5E-06
Pb-214	6E-06
Bi-214	1E-05
Rn-220	1E-15
Po-216	2E-17
Pb-212	7E-16
Bi-212	4E-16
Total	2E-05

Table 7-87. Summary of Risks for the Residential Farmer from Radon—1,000 years, 216-Z-9 Trench.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	2E-06
Po-218	5E-06
Pb-214	6E-06
Bi-214	1E-05
Rn-220	2E-15
Po-216	3E-17
Pb-212	1E-15
Bi-212	6E-16
Total	2E-05

Table 7-88. Summary of Risks for the Residential Farmer from External Radiation—150 years, 216-Z-9 Trench.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	1E-05
Am-241	4E-03
Eu-152	1E-07
Np-237	2E-04
Pa-231	2E-06
Pb-210	1E-07
Pu-238	1E-07
Pu-239	3E-03
Pu-240	2E-04
Ra-226	2E-04
Ra-228	4E-13
Sr-90	5E-09
Tc-99	1E-18
Th-228	9E-13
Th-229	1E-10
Th-230	3E-08
Th-232	3E-18
U-233	8E-11
U-234	2E-10
U-235	8E-07
U-236	1E-09
Total	7E-03

Table 7-89. Summary of Risks for the Residential Farmer from External Radiation—500 years, 216-Z-9 Trench.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	5E-11
Am-241	1E-22
Eu-152	2E-19
Np-237	5E-06
Pa-231	2E-11
Pb-210	2E-09
Pu-238	1E-09
Pu-239	2E-03
Pu-240	1E-04
Ra-226	4E-06
Ra-228	2E-13
Sr-90	3E-27
Tc-99	0E+00
Th-228	3E-13
Th-229	7E-10
Th-230	3E-08
Th-232	2E-17
U-233	9E-13
U-234	5E-13
U-235	1E-07
U-236	2E-10
Total	2E-03

Table 7-90. Summary of Risks for the Residential Farmer from External Radiation—1,000 years, 216-Z-9 Trench.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	3E-11
Am-241	0E+00
Eu-152	0E+00
Np-237	1E-07
Pa-231	1E-11
Pb-210	2E-09
Pu-238	2E-11
Pu-239	1E-03
Pu-240	8E-05
Ra-226	4E-06
Ra-228	3E-13
Sr-90	0E+00
Tc-99	0E+00
Th-228	5E-13
Th-229	7E-10
Th-230	3E-08
Th-232	3E-17
U-233	3E-14
U-234	6E-15
U-235	8E-08
U-236	1E-10
Total	1E-03

216-Z-9 Trench – Well Driller

Table 7-91. Summary of Risks for the Well Driller from Soil—150 years 216-Z-9 Trench.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	3E-11	8E-13	3E-11
Am-241	1E-07	2E-09	1E-07
Eu-152	1E-15	2E-18	1E-15
Gd-152	5E-30	0E+00	5E-30
Ni-63	4E-12	2E-15	4E-12
Np-237	5E-11	1E-12	5E-11
Pa-231	1E-11	3E-13	1E-11
Pb-210	3E-10	2E-13	3E-10
Pu-238	7E-10	2E-11	7E-10
Pu-239	6E-06	1E-07	6E-06
Pu-240	1E-06	3E-08	1E-06
Ra-226	4E-11	2E-13	4E-11
Ra-228	1E-18	3E-21	1E-18
Sr-90	1E-13	5E-17	1E-13
Tc-99	1E-21	7E-25	1E-21
Th-228	5E-19	1E-20	5E-19
Th-229	1E-17	2E-19	1E-17
Th-230	1E-11	2E-13	1E-11
Th-232	1E-22	2E-24	1E-22
U-233	3E-14	6E-16	3E-14
U-234	3E-13	6E-15	3E-13
U-235	5E-13	8E-15	5E-13
U-236	3E-12	6E-14	3E-12
Total	8E-06	2E-07	7E-06

Table 7-92. Summary of Risks for the Well Driller from Soil—500 years
216-Z-9 Trench.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	2E-18	3E-20	1E-18
Am-241	0E+00	0E+00	0E+00
Eu-152	2E-28	0E+00	2E-28
Gd-152	7E-30	0E+00	7E-30
Ni-63	8E-15	3E-18	8E-15
Np-237	2E-15	4E-17	2E-15
Pa-231	5E-18	1E-19	5E-18
Pb-210	8E-13	5E-16	8E-13
Pu-238	5E-12	1E-13	4E-12
Pu-239	2E-06	4E-08	2E-06
Pu-240	4E-07	9E-09	4E-07
Ra-226	3E-13	1E-15	3E-13
Ra-228	4E-20	1E-22	4E-20
Sr-90	0E+00	0E+00	0E+00
Tc-99	0E+00	0E+00	0E+00
Th-228	1E-20	3E-22	1E-20
Th-229	3E-16	7E-18	3E-16
Th-230	1E-11	3E-13	1E-11
Th-232	7E-21	2E-22	7E-21
U-233	9E-20	2E-21	9E-20
U-234	8E-17	1E-18	7E-17
U-235	1E-14	2E-16	1E-14
U-236	6E-14	1E-15	6E-14
Total	2E-06	5E-08	2E-06

Table 7-93. Summary of Risks for the Well Driller from Soil—1,000 years 216-Z-9 Trench.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	4E-19	9E-21	4E-19
Am-241	0E+00	0E+00	0E+00
Eu-152	0E+00	0E+00	0E+00
Gd-152	0E+00	0E+00	0E+00
Ni-63	1E-17	6E-21	1E-17
Np-237	5E-20	1E-21	5E-20
Pa-231	1E-18	3E-20	1E-18
Pb-210	7E-13	5E-16	7E-13
Pu-238	2E-14	5E-16	2E-14
Pu-239	5E-07	1E-08	5E-07
Pu-240	1E-07	2E-09	1E-07
Ra-226	3E-13	1E-15	3E-13
Ra-228	5E-20	1E-22	5E-20
Sr-90	0E+00	0E+00	0E+00
Tc-99	0E+00	0E+00	0E+00
Th-228	2E-20	4E-22	1E-20
Th-229	3E-16	6E-18	3E-16
Th-230	1E-11	2E-13	1E-11
Th-232	8E-21	2E-22	8E-21
U-233	3E-24	5E-26	3E-24
U-234	4E-19	7E-21	4E-19
U-235	3E-15	5E-17	3E-15
U-236	1E-14	3E-16	1E-14
Total	6E-07	1E-08	6E-07

Table 7-94. Summary of Risks for the Well Driller from Radon—150 years 216-Z-9 Trench.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	3E-11
Po-218	1E-13
Pb-214	4E-17
Rn-220	4E-17
Po-216	5E-19
Pb-212	7E-20
Bi-212	6E-24
Total	3E-11

Table 7-95. Summary of Risks for the Well Driller from Radon—500 years 216-Z-9 Trench.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	2E-13
Po-218	1E-15
Pb-214	3E-19
Rn-220	1E-18
Po-216	1E-20
Pb-212	2E-21
Bi-212	1E-25
Total	2E-13

Table 7-96. Summary of Risks for the Well Driller from Radon—1,000 years 216-Z-9 Trench.

Radionuclide (Parent and Decay)	Inhalation
Rn-222	2E-13
Po-218	1E-15
Pb-214	3E-19
Rn-220	1E-18
Po-216	2E-20
Pb-212	2E-21
Bi-212	2E-25
Total	2E-13

Table 7-97. Summary of Risks for the Well Driller from External Radiation—150 years, 216-Z-9 Trench.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	1E-08
Am-241	7E-06
Eu-152	1E-10
Np-237	7E-08
Pa-231	1E-09
Pb-210	7E-11
Pu-238	9E-11
Pu-239	1E-06
Pu-240	2E-07
Ra-226	8E-08
Ra-228	5E-16
Sr-90	5E-12
Tc-99	5E-21
Th-228	1E-15
Th-229	3E-15
Th-230	2E-11
Th-232	6E-23
U-233	5E-14
U-234	2E-13
U-235	5E-10
U-236	1E-12
Total	8E-06

Table 7-98. Summary of Risks for the Well Driller from External Radiation—500 years, 216-Z-9 Trench.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	5E-16
Am-241	0E+00
Eu-152	2E-23
Np-237	3E-12
Pa-231	5E-16
Pb-210	2E-13
Pu-238	6E-13
Pu-239	4E-07
Pu-240	5E-08
Ra-226	6E-10
Ra-228	2E-17
Sr-90	0E+00
Tc-99	0E+00
Th-228	3E-17
Th-229	8E-14
Th-230	2E-11
Th-232	4E-21
U-233	2E-19
U-234	5E-17
U-235	1E-11
U-236	2E-14
Total	5E-07

Table 7-99. Summary of Risks for the Well Driller from External Radiation—1,000 years, 216-Z-9 Trench.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	1E-16
Am-241	0E+00
Eu-152	0E+00
Np-237	7E-17
Pa-231	1E-16
Pb-210	2E-13
Pu-238	3E-15
Pu-239	1E-07
Pu-240	1E-08
Ra-226	6E-10
Ra-228	2E-17
Sr-90	0E+00
Tc-99	0E+00
Th-228	3E-17
Th-229	7E-14
Th-230	2E-11
Th-232	5E-21
U-233	5E-24
U-234	2E-19
U-235	3E-12
U-236	5E-15
Total	1E-07

216-A-8 Crib – Residential

Table 7-100. Summary of Risks for the Residential Farmer from Soil—150 years 216-A-8 Crib.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	3E-20	3E-22	3E-20
C-14	0E+00	0E+00	0E+00
Cs-137	1E-06	2E-10	1E-06
Np-237	2E-09	2E-11	2E-09
Pa-231	6E-20	9E-22	6E-20
Pu-239	3E-08	3E-10	3E-08
Pu-240	6E-09	7E-11	6E-09
Ra-228	1E-14	1E-17	1E-14
Tc-99	8E-25	3E-28	8E-25
Th-228	6E-15	8E-17	6E-15
Th-229	7E-16	9E-18	7E-16
Th-232	8E-25	1E-26	8E-25
U-233	1E-13	1E-15	9E-14
U-235	2E-16	2E-18	2E-16
U-236	1E-15	1E-17	1E-15
Total	1E-06	6E-10	1E-06

Table 7-101. Summary of Risks for the Residential Farmer from Soil–500 years 216-A-8 Crib.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	3E-19	4E-21	3E-19
C-14	0E+00	0E+00	0E+00
Cs-137	1E-11	1E-15	1E-11
Np-237	6E-11	7E-13	6E-11
Pa-231	4E-19	5E-21	4E-19
Pu-239	2E-08	2E-10	2E-08
Pu-240	4E-09	4E-11	4E-09
Ra-228	6E-22	8E-25	6E-22
Tc-99	0E+00	0E+00	0E+00
Th-228	2E-22	2E-24	2E-22
Th-229	2E-14	3E-16	2E-14
Th-232	7E-23	9E-25	7E-23
U-233	9E-15	1E-16	9E-15
U-235	3E-16	3E-18	3E-16
U-236	2E-15	2E-17	2E-15
Total	2E-08	3E-10	2E-08

Table 7-102. Summary of Risks for the Residential Farmer from Soil—1,000 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	2E-19	2E-21	2E-19
C-14	0E+00	0E+00	0E+00
Cs-137	9E-17	1E-20	9E-17
Np-237	2E-12	2E-14	2E-12
Pa-231	2E-19	3E-21	2E-19
Pu-239	1E-08	1E-10	1E-08
Pu-240	2E-09	3E-11	2E-09
Ra-228	1E-21	1E-24	1E-21
Tc-99	0E+00	0E+00	0E+00
Th-228	3E-22	4E-24	3E-22
Th-229	2E-14	3E-16	2E-14
Th-232	1E-22	1E-24	1E-22
U-233	3E-16	3E-18	3E-16
U-235	2E-16	2E-18	2E-16
U-236	1E-15	1E-17	9E-16
Total	1E-08	2E-10	1E-08

Table 7-103. Summary of Risks for the Residential Farmer from Produce—150 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	Produce
Ac-227	5E-19
C-14	0E+00
Cs-137	4E-04
Np-237	3E-07
Pa-231	5E-18
Pu-239	2E-07
Pu-240	4E-08
Ra-228	3E-12
Tc-99	3E-20
Th-228	5E-14
Th-229	5E-15
Th-232	6E-24
U-233	2E-12
U-235	3E-15
U-236	2E-14
Total	4E-04

Table 7-104. Summary of Risks for the Residential Farmer from Produce—500 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	Produce
Ac-227	5E-18
C-14	0E+00
Cs-137	3E-09
Np-237	8E-09
Pa-231	3E-17
Pu-239	1E-07
Pu-240	3E-08
Ra-228	2E-19
Tc-99	0E+00
Th-228	2E-21
Th-229	2E-13
Th-232	5E-22
U-233	2E-13
U-235	5E-15
U-236	3E-14
Total	2E-07

Table 7-105. Summary of Risks for the Residential Farmer from Produce—1,000 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	Produce
Ac-227	3E-18
C-14	0E+00
Cs-137	2E-14
Np-237	2E-10
Pa-231	2E-17
Pu-239	7E-08
Pu-240	2E-08
Ra-228	3E-19
Tc-99	0E+00
Th-228	3E-21
Th-229	2E-13
Th-232	8E-22
U-233	5E-15
U-235	3E-15
U-236	2E-14
Total	9E-08

Table 7-106. Summary of Risks for the Residential Farmer from Radon—150 years 216-A-8 Crib.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	6E-14
Po-216	9E-16
Pb-212	3E-14
Bi-212	2E-14
Total	1E-13

Table 7-107. Summary of Risks for the Residential Farmer from Radon—500 years 216-A-8 Crib.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	2E-21
Po-216	3E-23
Pb-212	1E-21
Bi-212	6E-22
Total	4E-21

Table 7-108. Summary of Risks for the Residential Farmer from Radon—1,000 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	3E-21
Po-216	5E-23
Pb-212	2E-21
Bi-212	9E-22
Total	6E-21

Table 7-109. Summary of Risks for the Residential Farmer from External Radiation—150 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	1E-17
C-14	0E+00
Cs-137	2E-02
Np-237	3E-06
Pa-231	7E-18
Pu-239	5E-09
Pu-240	5E-10
Ra-228	6E-12
Tc-99	3E-24
Th-228	2E-11
Th-229	2E-13
Th-232	4E-25
U-233	2E-13
U-235	2E-13
U-236	3E-16
Total	2E-02

Table 7-110. Summary of Risks for the Residential Farmer from External Radiation—500 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	1E-16
C-14	0E+00
Cs-137	1E-07
Np-237	8E-08
Pa-231	4E-17
Pu-239	3E-09
Pu-240	3E-10
Ra-228	3E-19
Tc-99	0E+00
Th-228	5E-19
Th-229	7E-12
Th-232	3E-23
U-233	2E-14
U-235	3E-13
U-236	4E-16
Total	2E-07

Table 7-111. Summary of Risks for the Residential Farmer from External Radiation—1,000 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	7E-17
C-14	0E+00
Cs-137	1E-12
Np-237	3E-09
Pa-231	2E-17
Pu-239	2E-09
Pu-240	2E-10
Ra-228	5E-19
Tc-99	0E+00
Th-228	8E-19
Th-229	6E-12
Th-232	5E-23
U-233	5E-16
U-235	2E-13
U-236	2E-16
Total	5E-09

216-A-8 Crib – Well Driller

Table 7-112. Summary of Risks for the Well Driller from Soil—150 years 216-A-8 Crib.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	1E-27	2E-29	1E-27
Cs-137	8E-10	2E-13	8E-10
Np-237	8E-13	2E-14	8E-13
Pa-231	5E-26	1E-27	5E-26
Pu-239	1E-11	2E-13	1E-11
Pu-240	2E-12	5E-14	2E-12
Ra-228	2E-17	4E-20	2E-17
Th-228	9E-18	2E-19	9E-18
Th-229	4E-22	1E-23	4E-22
Th-232	1E-31	0E+00	1E-31
U-233	2E-18	4E-20	2E-18
U-235	3E-21	5E-23	3E-21
U-236	2E-20	4E-22	2E-20
Total	8E-10	5E-13	8E-10

Table 7-113. Summary of Risks for the Well Driller from Soil—500 years 216-A-8 Crib.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	2E-24	5E-26	2E-24
Cs-137	4E-15	9E-19	4E-15
Np-237	2E-17	5E-19	2E-17
Pa-231	7E-24	2E-25	7E-24
Pu-239	3E-12	6E-14	3E-12
Pu-240	6E-13	1E-14	6E-13
Ra-228	4E-26	9E-29	4E-26
Th-228	1E-26	3E-28	1E-26
Th-229	1E-18	2E-20	1E-18
Th-232	7E-27	1E-28	6E-27
U-233	1E-21	2E-23	1E-21
U-235	1E-20	3E-22	1E-20
U-236	9E-20	2E-21	9E-20
Total	3E-12	7E-14	3E-12

Table 7-114. Summary of Risks for the Well Driller from Soil—1,000 years
216-A-8 Crib.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	5E-25	1E-26	5E-25
Cs-137	2E-20	5E-24	2E-20
Np-237	6E-22	1E-23	6E-22
Pa-231	2E-24	4E-26	2E-24
Pu-239	7E-13	2E-14	7E-13
Pu-240	1E-13	3E-15	1E-13
Ra-228	5E-26	1E-28	5E-26
Th-228	2E-26	4E-28	2E-26
Th-229	1E-18	2E-20	1E-18
Th-232	8E-27	2E-28	8E-27
U-233	3E-26	7E-28	3E-26
U-235	4E-21	7E-23	4E-21
U-236	2E-20	4E-22	2E-20
Total	9E-13	2E-14	8E-13

Table 7-115. Summary of Risks for the Well Driller from Radon—150 years
216-A-8 Crib

Radionuclide (Parent and Decay)	Inhalation
Rn-220	7E-16
Po-216	9E-18
Pb-212	1E-18
Bi-212	9E-23
Total	7E-16

Table 7-116. Summary of Risks for the Well Driller from Radon—500 years
216-A-8 Crib.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	1E-24
Po-216	1E-26
Pb-212	2E-27
Bi-212	0E+00
Total	1E-24

Table 7-117. Summary of Risks for the Well Driller from Radon—1,000 years 216-A-8 Crib.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	1E-24
Po-216	2E-26
Pb-212	2E-27
Bi-212	0E+00
Total	1E-24

Table 7-118. Summary of Risks for the Well Driller from External Radiation—150 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	4E-25
Cs-137	7E-06
Np-237	1E-09
Pa-231	4E-24
Pu-239	2E-12
Pu-240	3E-13
Ra-228	8E-15
Th-228	2E-14
Th-229	1E-19
Th-232	0E+00
U-233	3E-18
U-235	3E-18
U-236	6E-21
Total	7E-06

Table 7-119. Summary of Risks for the Well Driller from External Radiation—500 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	7E-22
Cs-137	4E-11
Np-237	3E-14
Pa-231	7E-22
Pu-239	6E-13
Pu-240	7E-14
Ra-228	2E-23
Th-228	3E-23
Th-229	3E-16
Th-232	4E-27
U-233	2E-21
U-235	1E-17
U-236	3E-20
Total	4E-11

Table 7-120. Summary of Risks for the Well Driller from External Radiation—1,000 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	2E-22
Cs-137	2E-16
Np-237	9E-19
Pa-231	2E-22
Pu-239	2E-13
Pu-240	2E-14
Ra-228	2E-23
Th-228	3E-23
Th-229	2E-16
Th-232	5E-27
U-233	6E-26
U-235	4E-18
U-236	7E-21
Total	2E-13

216-A-8 Crib – Construction Worker

Table 7-121. Summary of Risks for the Construction Worker from Soil—Now, 216-A-8 Crib.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	1E-23	2E-24	8E-24
Cs-137	3E-04	6E-07	3E-04
Np-237	4E-09	6E-10	3E-09
Pa-231	4E-22	7E-23	4E-22
Pu-239	9E-08	2E-08	8E-08
Pu-240	2E-08	4E-09	2E-08
Ra-228	1E-08	3E-10	1E-08
Th-228	4E-09	7E-10	3E-09
Th-229	2E-18	3E-19	2E-18
Th-232	4E-27	7E-28	3E-27
U-233	9E-15	1E-15	7E-15
U-235	3E-17	3E-18	2E-17
U-236	2E-16	2E-17	1E-16
Total	3E-04	6E-07	3E-04

Table 7-122. Summary of Risks for the Construction Worker from Soil—17 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	2E-19	3E-20	2E-19
Cs-137	2E-04	4E-07	2E-04
Np-237	4E-09	6E-10	3E-09
Pa-231	4E-19	7E-20	3E-19
Pu-239	9E-08	2E-08	8E-08
Pu-240	2E-08	4E-09	2E-08
Ra-228	2E-09	4E-11	2E-09
Th-228	1E-09	2E-10	8E-10
Th-229	2E-15	3E-16	2E-15
Th-232	4E-24	6E-25	3E-24
U-233	3E-13	5E-14	3E-13
U-235	9E-16	1E-16	8E-16
U-236	6E-15	9E-16	5E-15
Total	2E-04	4E-07	2E-04

Table 7-123. Summary of Risks for the Construction Worker from Soil—28 years 216-A-8 Crib.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	7E-19	1E-19	6E-19
Cs-137	2E-04	3E-07	2E-04
Np-237	4E-09	6E-10	3E-09
Pa-231	1E-18	2E-19	9E-19
Pu-239	9E-08	2E-08	8E-08
Pu-240	2E-08	4E-09	2E-08
Ra-228	5E-10	1E-11	5E-10
Th-228	3E-10	5E-11	2E-10
Th-229	5E-15	8E-16	4E-15
Th-232	1E-23	2E-24	8E-24
U-233	5E-13	8E-14	4E-13
U-235	1E-15	2E-16	1E-15
U-236	9E-15	1E-15	8E-15
Total	2E-04	3E-07	2E-04

Table 7-124. Summary of Risks for the Construction Worker from Soil—150 years 216-A-8 Crib.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	5E-17	9E-18	4E-17
Cs-137	1E-05	2E-08	1E-05
Np-237	4E-09	6E-10	3E-09
Pa-231	3E-17	5E-18	2E-17
Pu-239	9E-08	2E-08	8E-08
Pu-240	2E-08	3E-09	2E-08
Ra-228	2E-16	4E-18	2E-16
Th-228	1E-16	2E-17	9E-17
Th-229	1E-13	2E-14	1E-13
Th-232	3E-22	4E-23	2E-22
U-233	3E-12	4E-13	2E-12
U-235	7E-15	1E-15	6E-15
U-236	5E-14	7E-15	4E-14
Total	1E-05	4E-08	1E-05

Table 7-125. Summary of Risks for the Construction Worker from Soil—500 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	7E-16	1E-16	6E-16
Cs-137	3E-09	6E-12	3E-09
Np-237	4E-09	6E-10	3E-09
Pa-231	3E-16	5E-17	2E-16
Pu-239	9E-08	2E-08	8E-08
Pu-240	2E-08	3E-09	2E-08
Ra-228	2E-20	5E-22	2E-20
Th-228	9E-21	2E-21	7E-21
Th-229	1E-12	2E-13	1E-12
Th-232	3E-21	5E-22	2E-21
U-233	8E-12	1E-12	7E-12
U-235	2E-14	3E-15	2E-14
U-236	1E-13	2E-14	1E-13
Total	1E-07	2E-08	1E-07

Table 7-126. Summary of Risks for the Construction Worker from Soil—1,000 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	Total	Inhalation	Ingestion
Ac-227	3E-15	5E-16	2E-15
Cs-137	3E-14	6E-17	3E-14
Np-237	4E-09	6E-10	3E-09
Pa-231	1E-15	2E-16	9E-16
Pu-239	9E-08	2E-08	8E-08
Pu-240	2E-08	3E-09	2E-08
Ra-228	9E-20	2E-21	9E-20
Th-228	3E-20	6E-21	3E-20
Th-229	5E-12	9E-13	4E-12
Th-232	1E-20	2E-21	9E-21
U-233	1E-11	2E-12	1E-11
U-235	4E-14	6E-15	4E-14
U-236	3E-13	4E-14	2E-13
Total	1E-07	2E-08	9E-08

Table 7-127. Summary of Risks for the Construction Worker from Radon—Now, 216-A-8 Crib.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	1E-08
Po-216	2E-10
Pb-212	1E-10
Bi-212	4E-14
Total	1E-08

Table 7-128. Summary of Risks for the Construction Worker from Radon—17 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	3E-09
Po-216	4E-11
Pb-212	3E-11
Bi-212	1E-14
Total	3E-09

Table 7-129. Summary of Risks for the Construction Worker from Radon—28 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	7E-10
Po-216	1E-11
Pb-212	8E-12
Bi-212	3E-15
Total	8E-10

Table 7-130. Summary of Risks for the Construction Worker from Radon—150 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	3E-16
Po-216	5E-18
Pb-212	3E-18
Bi-212	1E-21
Total	3E-16

Table 7-131. Summary of Risks for the Construction Worker from Radon—500 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	2E-20
Po-216	4E-22
Pb-212	2E-22
Bi-212	8E-26
Total	2E-20

Table 7-132. Summary of Risks for the Construction Worker from Radon—1,000 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	Inhalation
Rn-220	9E-20
Po-216	1E-21
Pb-212	9E-22
Bi-212	3E-25
Total	9E-20

Table 7-133. Summary of Risks for the Construction Worker from External Radiation—Now, 216-A-8 Crib.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	4E-23
Cs-137	5E-02
Np-237	7E-08
Pa-231	5E-22
Pu-239	2E-10
Pu-240	2E-11
Ra-228	1E-07
Th-228	1E-07
Th-229	7E-18
Th-232	2E-29
U-233	2E-16
U-235	3E-16
U-236	5E-19
Total	5E-02

Table 7-134. Summary of Risks for the Construction Worker from External Radiation—17 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	8E-19
Cs-137	4E-02
Np-237	7E-08
Pa-231	5E-19
Pu-239	2E-10
Pu-240	2E-11
Ra-228	1E-08
Th-228	4E-08
Th-229	6E-15
Th-232	2E-26
U-233	7E-15
U-235	1E-14
U-236	2E-17
Total	4E-02

Table 7-135. Summary of Risks for the Construction Worker from External Radiation—28 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	3E-18
Cs-137	3E-02
Np-237	7E-08
Pa-231	1E-18
Pu-239	2E-10
Pu-240	2E-11
Ra-228	4E-09
Th-228	1E-08
Th-229	2E-14
Th-232	5E-26
U-233	1E-14
U-235	2E-14
U-236	3E-17
Total	3E-02

Table 7-136. Summary of Risks for the Construction Worker from External Radiation—150 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	2E-16
Cs-137	2E-03
Np-237	7E-08
Pa-231	4E-17
Pu-239	2E-10
Pu-240	2E-11
Ra-228	2E-15
Th-228	4E-15
Th-229	5E-13
Th-232	1E-24
U-233	6E-14
U-235	9E-14
U-236	1E-16
Total	2E-03

Table 7-137. Summary of Risks for the Construction Worker from External Radiation—500 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	3E-15
Cs-137	5E-07
Np-237	7E-08
Pa-231	4E-16
Pu-239	2E-10
Pu-240	2E-11
Ra-228	2E-19
Th-228	3E-19
Th-229	5E-12
Th-232	2E-23
U-233	2E-13
U-235	3E-13
U-236	4E-16
Total	6E-07

Table 7-138. Summary of Risks for the Construction Worker from External Radiation—1,000 years, 216-A-8 Crib.

Radionuclide (Parent and Decay)	External Radiation
Ac-227	1E-14
Cs-137	5E-12
Np-237	7E-08
Pa-231	1E-15
Pu-239	2E-10
Pu-240	2E-11
Ra-228	7E-19
Th-228	1E-18
Th-229	2E-11
Th-232	6E-23
U-233	3E-13
U-235	5E-13
U-236	8E-16
Total	7E-08

APPENDIX A

ATTACHMENT 8

RISK-BASED CONCENTRATIONS FOR GROUNDWATER AND SOIL RESRAD SUMMARIES

ATTACHMENT 8
TABLE OF CONTENTS

Table 8-1. RBCs for Industrial Exposures to Tap Water (Radioactive Chemicals).

Ingestion of Groundwater

Risk-Based Concentration Calculation

Exposure Medium: Groundwater

Exposure Point: Drinking Water

Receptor Population: Industrial

Cancer RBC = TCR / (CSF x SIFc)

Receptor Age: Lifetime

Parameter	Unit	RME Lifetime
Chemical Conc'n in Water (CW)	pCi/L	chem-specific
Ingestion Rate of Water (IR)	L/day	1
Exposure Frequency (EF)	days/yr	250
Exposure Duration (ED)	years	25
SIFc = (IR*EF*ED)	L	6.25E+03

Chemical	Target Cancer Risk	RBC Cancer (pCi/L)
I-129	1.00E-04	107
Tc-99	1.00E-04	5,818
Tritium	1.00E-04	31,582

Chemical	CSFo (risk/pCi)
I-129 (non-dairy)	1.5E-10
Tc-99	2.75E-12
Tritium	5.07E-14

RBC = risk-based concentration
TCR = target cancer risk
CSF = cancer slope factor
SIFc = summary intake factor-cancer

Table 8-2. RBCs for Industrial Exposures to Tap Water (Radioactive Chemicals).

Inhalation of Vapor

Risk-Based Concentration Calculation

Exposure Medium: Groundwater

Exposure Point: Drinking Water

Receptor Population: Industrial

Receptor Age: Lifetime

Cancer RBC = TCR / (CSF x SIFc x VFw)

Parameter	Units	RME Lifetime
Chemical Concentration in Water (CW)	pCi/L	chem-specific
Inhalation Rate of Air (InhR)	m^3/hr	1.6
Exposure Time (ET)	hr/day	3
Exposure Frequency (EF)	days/yr	250
Exposure Duration (ED)	years	25
SIFc = (InhR*EF*ED*VF)	m^3	3.0E+04

Chemical	CSFi (risk/pCi)	VF (L/m^3)
I-129 (non-dairy)	1.60E-10	--
Tc-99	--	--
Tritium	5.62E-14	0.011675

Chemical	Target Cancer Risk	RBC Cancer (pCi/L)
I-129	1.00E-04	--
Tc-99	1.00E-04	--
Tritium	1.00E-04	5,080,255

RBC = risk-based concentration
TCR = target cancer risk
CSF = cancer slope factor
SIFc = summary intake factor-cancer
VF = volatilization factor

Table 8-3. RBCs for Industrial Exposures to Tap Water (Radioactive Chemicals).

Combined Inhalation and Ingestion Exposures

Risk-Based Concentration Calculation

Exposure Medium: Groundwater

Exposure Point: Drinking Water

Receptor Population: Industrial

Receptor Age: Lifetime

combined RBC = $(RBC_{ing} \times RBC_{inh}) / (RBC_{ing} + RBC_{inh})$

RBCs for Combined Exposures to Contaminants in Groundwater (ingestion and inhalation)	
Chemical	**Cancer**
I-129	107
Tc-99	5,818
Tritium	297,125

RBCing = risk-based concentration for ingestion exposures
RBCinh = risk-based concentration for inhalation exposures

Table 8-4. RBCs for Industrial Exposures to Tap Water (Nonradioactive Chemicals). (2 sheets)

Ingestion of Groundwater
Risk-Based Concentration Calculation

Exposure Medium: Groundwater
Exposure Point: Drinking Water
Receptor Population: Industrial Workers
Receptor Age: Adults

Non-Cancer RBC = RfD x THQ / SIFnc
Cancer RBC = TCR / (CSF x SIFc)

Parameter	Unit	Adult
Chemical Conc'n in Water (CW)	ug/L	chem-specific
Ingestion Rate of Water (IR)	L/day	1
Exposure frequency (EF)	unitless	250
Exposure Duration non-cancer (ED-nc)	years	25
Exposure duration-cancer (ED-ca)	years	25
Body weight (BW)	kg	70
Conversion Factor (CF)	mg/ug	1.00E-03
Averaging time (non-cancer) (ATnc)	years	9,125
Averaging time (cancer) (ATc)	years	25,550
Drinking Water Fraction (DWF)	unitless	1
SIFnc = (IR*EF*ED-nc*DWF*CF)/(BW*ATnc)	L-mg/ug-kg-d	9.78E-06
SIFc = (IR*ED-ca*EF*DWF*CF)/(BW*Atc)	L-mg/ug-kg-d	3.49E-06

Chemical	RfDo (mg/kg-d)	CSFo $(mg/kg\text{-}d)^{-1}$
Carbon Tetrachloride	7.00E-04	1.30E-01
Chloroform	1.00E-02	--
Chromium III	1.50E+00	--
Chromium VI (groundwater)	3.00E-03	--
Methylene Chloride	6.00E-02	7.50E-03
Nitrate	1.60E+00	--
PCE	1.00E-02	5.40E-01
TCE	3.00E-04	3.10E-02
Uranium	3.00E-03	--

	THQ unitless	TCR unitless	NC RBC-adult ug/L	CA RBC ug/L
Carbon Tetrachloride	1	1.0E-04	7.2E+01	2.2E+02
Chloroform	1	1.0E-04	1.0E+03	--
Total Chromium	1	1.0E-04	1.5E+05	--
Chromium VI	1	1.0E-04	3.1E+02	--
Methylene Chloride	1	1.0E-04	6.1E+03	3.8E+03
Nitrate	1	1.0E-04	1.6E+05	--
PCE	1	1.0E-04	1.0E+03	5.3E+01
TCE	1	1.0E-04	3.1E+01	9.2E+02
	THQ	TCR	NC RBC-	CA RBC

Table 8-4. RBCs for Industrial Exposures to Tap Water (Nonradioactive Chemicals). (2 sheets)

Ingestion of Groundwater
Risk-Based Concentration Calculation

	unitless	unitless	adult ug/L	ug/L
Uranium	1	1.0E-04	3.1E+02	--

THQ = target hazard quotient
TCR = target cancer risk
NC = non cancer
RBC = risk based concentration
CA = cancer

Table 8-5. RBCs for Industrial Exposures to Tap Water (Nonradioactive Chemicals).

Inhalation of Vapor

Risk-Based Concentration Calculation

Exposure Medium: Groundwater
Exposure Point: Drinking Water
Receptor Population: Industrial Worker
Receptor Age: Adults

Non-Cancer RBC = (RfD x THQ) / (SIFnc x VFw)
Cancer RBC = TCR / (CSF x SIFc x VFw)

Parameter	Unit	Adult
Chemical Conc'n in Water (CW)	ug/L	chem-specific
Inhalation Rate (InhR)	m^3/hr	1.6
Exposure Time (ET)	hr/day	3
Exposure Frequency (EF)	unitless	250
Exposure Duration (non-cancer) (ED-nc)	years	25
Exposure Duration (ED)	years	25
Body Weight (BW)	kg	70
Conversion Factor (CF)	mg/ug	1.0E-03
Averaging Time (non-cancer) (ATnc)	years	9,125
Averaging Time (cancer) (ATc)	years	25,550
SIFnc = (InhR*EF*ED*ET*CF)/(BW*ATnc)	m^3-mg/ug-kg-day	4.70E-05
SIFc = (InhR*ED*ET*EF*CF)/ATc	m^3-mg/ug-kg-day	1.68E-05

Chemical	RfDi (mg/kg-d)	CSFi (mg/kg-d)-1	VFw[a] (L/m^3)
Carbon Tetrachloride	1.1E-02	5.3E-02	5.0E-01
Chloroform	1.3E-02	8.1E-02	5.0E-01
Chromium III	--	--	--
Chromium VI (groundwater)	2.9E-05	2.9E+02	--
Methylene Chloride	8.6E-01	1.6E-03	5.0E-01
Nitrate	--	--	--
PCE	1.1E-01	2.1E-02	5.0E-01
TCE	1.1E-02	7.0E-03	5.0E-01
Uranium	--	--	--

[a]A volatilization factor (VFw) of 0.5 is only applicable for volatile chemicals.

	THQ unitless	TCR unitless	NC RBC-adult ug/L	CA RBC ug/L
Carbon Tetrachloride	1	1.0E-04	468	225.0
Chloroform	1	1.0E-04	554	147.2
Total Chromium	1	1.0E-04	--	--
Chromium VI	1	1.0E-04	--	--
Methylene Chloride	1	1.0E-04	36,622	7,452.1
Nitrate	1	1.0E-04	--	--
PCE	1	1.0E-04	4,684	567.8
TCE	1	1.0E-04	468	1,703
Uranium	1	1.0E-04	--	--

THQ = target hazard quotient
TCR = target cancer risk
NC = non cancer
RBC = Risk-based concentration
CA = cancer
SIF = Summary intake factor
VFw = volatilization factor for water
CSF = cancer slope factor
RfD = reference dose

Table 8-6. RBCs for Industrial Exposures to Tap Water (Nonradioactive Chemicals).

Combined Inhalation and Ingestion Exposures

Risk-Based Concentration Calculation

Exposure Medium: Groundwater

Exposure Point: Drinking Water

Receptor Population: Industrial Workers

Receptor Age: Adults

combined RBC for VOCs =(RBC_{ing} x RBC_{inh}) / (RBC_{ing} + RBC_{inh})

combined RBC for Metals = RBC_{ing}

	Chemical Class	NC RBC-adult ug/L	CA RBC ug/L	Tap Water RBC ug/L
Carbon Tetrachloride	VOC	62	111	62
Chloroform	VOC	359	147	147
Total Chromium	Metal	153,300	--	153,300
Chromium VI	Metal	307	--	307
Methylene Chloride	VOC	5,253	2,523	2,523
Nitrate	Other	163,520	--	163,520
PCE	VOC	839	48	48
TCE	VOC	29	960	29
Uranium	Metal	307	--	307

RBC = Risk-based concentration
CA = cancer
NC = non cancer

Table 8-7. RESRAD Summary of Pathway Risks for the Construction Worker Risk-Based Concentration (Based on Risk of 1 x 10^{-4}).

Chemical	RBC (pCi/g)	Total	Inhalation	Ingestion	External Radiation
Americium-241	45,000	1E-04	1E-05	6E-05	3E-05
Plutonium-239	50,000	1E-04	2E-05	9E-05	2E-07
Plutonium-240	50,000	1E-04	2E-05	9E-05	9E-08
Cesium-137	1,600	1E-04	1E-09	6E-07	1E-04

RBC = risk-based concentration